This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

+ *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.
+ *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.
+ *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.
+ *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

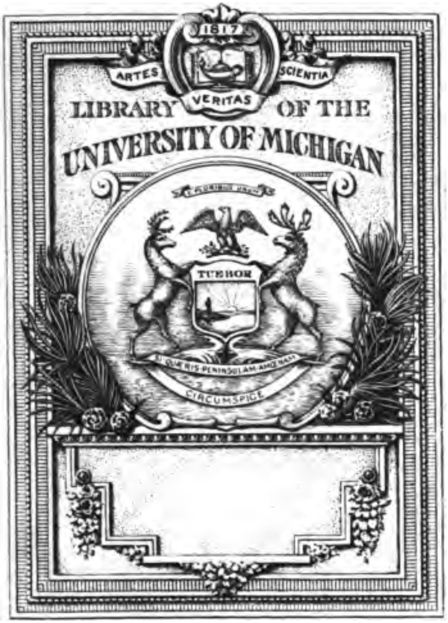
About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at `http://books.google.com/`

WALTER LOCK.

Q
1
.G
V.

TC


1817
ARTES
SCIENTIA
VERITAS
LIBRARY OF THE
UNIVERSITY OF MICHIGAN
E PLURIBUS UNUM
TUEBOR
SI QUAERIS PENINSULAM AMOENAM
CIRCUMSPICE

LECTURES

ON

EXPERIMENTAL PHILOSOPHY, ASTRONOMY, AND CHEMISTRY;

INTENDED CHIEFLY FOR THE USE OF STUDENTS AND YOUNG PERSONS.

BY G. GREGORY, D.D.

DOCTOR IN PHILOSOPHY AND THE ARTS, &c.

VICAR OF WEST-HAM; DOMESTIC CHAPLAIN TO THE LORD BISHOP OF LANDAFF; AND AUTHOR OF THE ECONOMY OF NATURE, DICTIONARY OF ARTS AND SCIENCES, &c. &c.

IN TWO VOLUMES.

VOL. II.

LONDON:

PRINTED FOR RICHARD PHILLIPS, BRIDGE-STREET, BLACKFRIARS,

BY RICHARD TAYLOR AND CO., SHOE-LANE.

1808.

ASTRONOMY.

PL. I VOL. II.

Fig. 1.

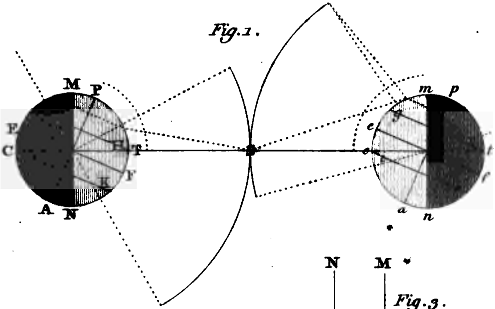


Fig. 2.

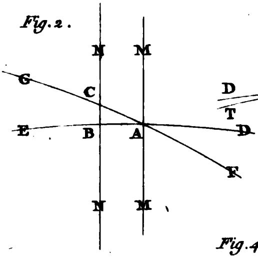


Fig. 3.

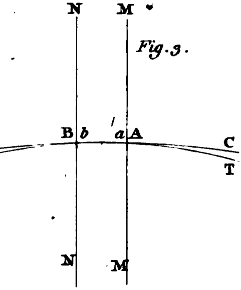
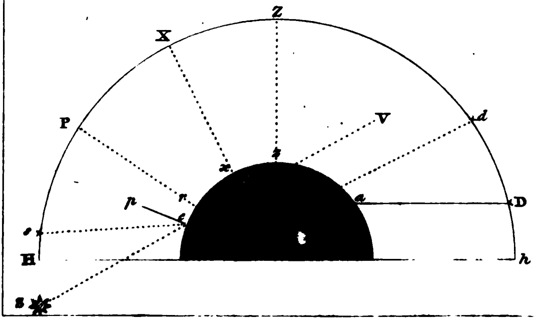


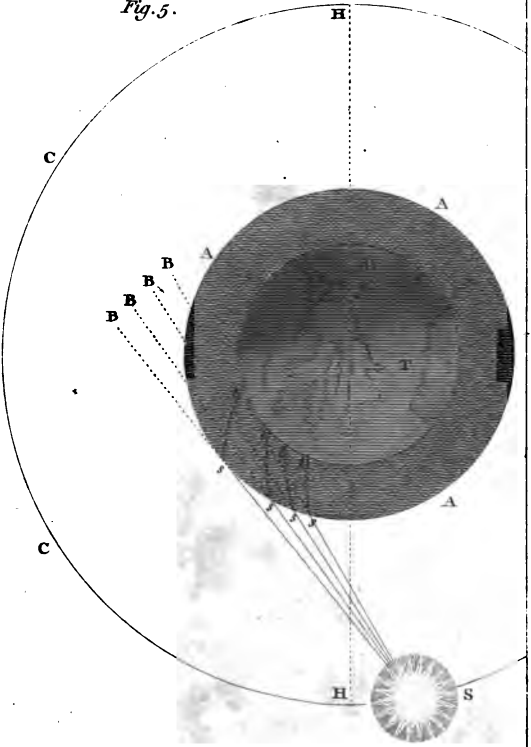
Fig. 4.



J. Farey Jun. del.

S. Porter sculp.

Fig. 5.



J. Farey Junr del.

S. Porter sculp.

UNIV. OF

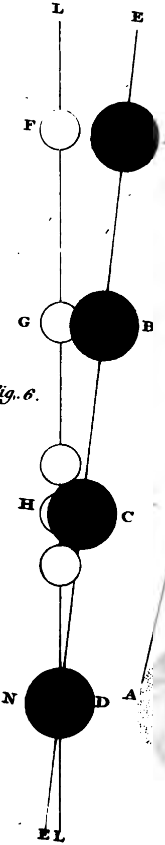


Fig. 6.

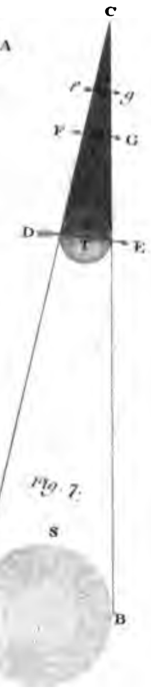


Fig. 7.

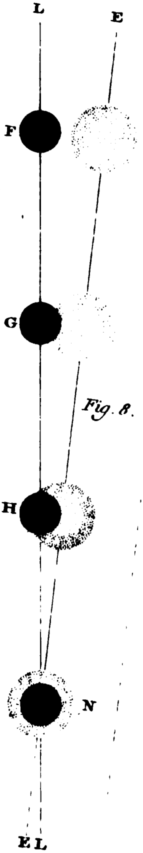


Fig. 8.

☉ ☾

J. Farey Jun.r del.

J. Porter sculp.

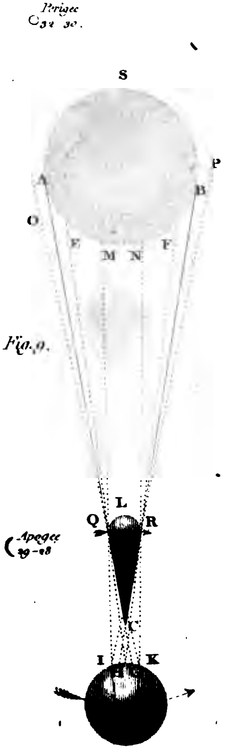


Fig. 9.

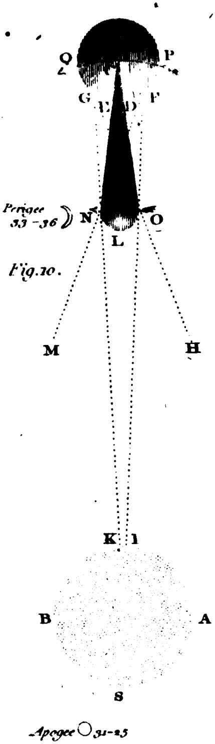


Fig. 10.

J. Farey Jun.r del. S. Porter sculp.

UNIV. H.

Hist of Science
Fletcher
8-28-44
50626

LECTURES
ON
EXPERIMENTAL PHILOSOPHY, &c.

LECTURE XXIII.

ASTRONOMY.

THE VICISSITUDES OF THE SEASONS, AND THE DIVISIONS OF TIME.

THE constant inclination of the axis of the earth to the plane of the ecliptic, and its parallelism, produce the vicissitudes of the seasons. That part of the earth which has the sun at midday as near to its zenith as possible, consistently with its latitude, enjoys the pleasant season of summer; and it is winter when the sun is as far distant as possible from its zenith. As, therefore, the track of the ecliptic lies between the two tropics, it is evident that our midsummer must be on the day of the summer solstice, or that on which the sun is vertical, or in the zenith, to all that part of the globe which is under the tropic of Cancer, and our midwinter or winter solstice must be on that day on which that part which lies under the tropic of Capricorn has the sun vertical, or in the zenith, and that period is midsummer to all that part of the southern hemisphere which lies beyond that tropic. Those places also which are situated under the equator will evidently have the sun in their zenith twice a year, at the time of the equinoxes.

In order that this vicissitude of seasons should take place, that is, that the solar rays should be vertical at the tropic of Cancer at the time of our summer solstice, at that of Capricorn at our winter solstice, and also at the equator at the time of the equinoxes, it is necessary that the axis of the earth should have an inclination of 23½ degrees to the plane of the ecliptic, and that this axis should preserve its parallelism during the whole of the earth's annual revolution.

To explain this more clearly by a diagram, let S (Pl. I. fig. 1.) be the sun; T and *t* two points diametrically opposite in the annual orbit of the earth; T the point where it is found towards the 21st of June; *t* the point where it is found towards the 21st of December; EF, or *ef*, the equator; I *t* the ecliptic or the orbit of the earth; GH, or *gh*, the tropic of Cancer at the distance of 23½ degrees from the equator; IK, or *ik*, the tropic of Capricorn at the same distance from the equator on the opposite side; PA, or *pa*, the axis of the earth; P, or *p*, the north pole; A, or *a*, the south pole. Now the equator of the earth being inclined at an angle of 23½ degrees to the ecliptic, the sun is bright so many degrees nearer to the north pole P about the 21st of June, and consequently he will be immediately over the point H in the tropic of Cancer, and all the places of the earth situated under the parallel GH will pass in their diurnal revolution directly under the sun. Six months after, the earth will be found on the other side of the sun in the point *t* of her orbit, diametrically opposite to the point T. Suppose then (which really takes place) that the axis *pa* is parallel to the axis PA, so as to point exactly to the same part of the heavens to which it pointed six months before. Now it is evident that the terminator MN, or *mn*, (drawn at right angles to I*t*) will divide the parallels to the equator or the circles of daily motion into unequal parts—those on the same side of the equator with the sun having a greater portion within the illumined than within the dark hemisphere. All the countries of the earth, therefore, which lie on this side of the equator will have their days longer than their nights, and of course enjoy summer. On the contrary, all the countries on the other side of the equator, having a greater portion of their parallels included within the dark than the illumined hemisphere, must have their nights longer than their days, and consequently it will be their winter. This is not only the case when the sun is at his greatest distances from the equator, or when he is in either of the tropics, but it takes place in a less degree at all his intermediate distances from it, the terminator continually dividing the parallels unequally, so as to comprehend a greater or a less portion of them within the illuminated part of the earth, according as the sun is on the same or a different side of the equator from that on which the parallels lie. When he is in the equator, the terminator will be in the direction PA, or *pa*, and will manifestly divide the parallels equally, so as to make day and night of the same length throughout the globe. This is the time of spring to the inhabitants of that part of the earth who are placed on the same side of the equator on which the sun is passing, and autumn to those who are placed on the other side of the equator from which he is retiring.

It is easy, therefore, to see that it is the inclination of the axis of the earth to the plane of the ecliptic, and its constant parallelism, which occasion the change of the seasons.

The sun being of all the heavenly bodies the most familiar to us, and the most easy of observation, has from the earliest ages furnished us with the measure of time. Time is divided into ages, years, months, weeks, days, hours, minutes, and seconds.

That space of time is called a day in which the earth performs one rotation on its axis, and in which consequently the sun appears to make an entire revolution round the earth from east to west. The natural or astronomical day is that in which the sun appears to revolve from the meridional line which passes through any given place to the same meridian again. The astronomical days are, however, not always of the same length, while the civil day is always of equal duration. This difference has given rise to a distinction which is necessary to be known. The former, which is usually measured by the sun-dial, is called solar, and the latter, which is measured by the clock, is called mean or equal time.

The difference between mean and solar time depends upon three causes.

1st, The earth (according to the third law of Kepler) does not pass equal portions of its orbit in equal times. It proceeds sometimes quicker, and sometimes slower, and consequently the sun appears to advance more or less rapidly in the ecliptic. In the first case the day will be somewhat longer, because the earth to rejoin the sun, or to present to him the same meridian, must make somewhat of a larger turn upon its axis. In the second case (for the opposite reason) the day will be in some degree shorter.

2dly, The earth's motion on its own axis is always equal and regular; and if the plane of the ecliptic was parallel to the equator, there would be no difference in the time marked by either of these circles, for fifteen degrees of each of these circles passing over any meridian would be equivalent to an hour in time. But, from the inclination of the earth's axis, as already described, the ecliptic is oblique to the equator, and consequently the earth's rotation on its axis carries unequal portions of the ecliptic over the meridian in equal times, and the difference is proportional to the obliquity. If a sun or star was, therefore, supposed to move in the circle of the equator, it would always return to the same meridian in twenty-four hours, as measured by the clock; but the sun, which moves in the ecliptic, will sometimes return sooner, and sometimes later. It is therefore only on four days in the year that these two luminaries would come both together to the same meridian, and on these days only the dial and the clock will be found exactly to agree.

A diagram will perhaps serve better to explain what I have now said. Let Pl. I. fig. 2. represent a part of the concave sphere of the heavens. Let DE be a part of the celestial equator, FG a part of the ecliptic, A the intersection of the two circles at the vernal equinox, AB a degree upon the equator. Suppose the plane of the meridian to pass from the situation MM into the situation NN, in going through the arc AB, one degree of the equator, it will go through the arc C more than one degree of the ecliptic. For in the triangle ABC, the angle at B is a right angle, and the hypothenuse AC is consequently the longest side.

At the solstices, the obliquity of the ecliptic has a contrary effect, and contributes to lengthen the solar days. Thus, (in fig. 3,) TT is part of the tropic of Capricorn, CD part of the ecliptic, coincident with the tropic for some distance on each side of the solstitial point, viz. from A to B, and therefore meridians which are perpendicular to the tropic may be considered so far as perpendicular to the ecliptic. A meridian, then, in going from A to B will go through as large an arc in the tropic as in the ecliptic; but the tropic not being so great a circle, any arc, as *ab*, taken in both these circles will measure more minutes than in the ecliptic, and that in proportion as the ecliptic exceeds the tropic in dimensions. The circumference of the ecliptic is to that of the tropic as 60 to 55, and therefore the arc *a b* of 55 minutes on the ecliptic, will be 60 in the tropic. As every meridian, therefore, passes in the same time through similar arcs in the celestial equator, and all circles parallel to the equator, and such are the tropics, at the solstices every arc of the ecliptic passed through by any meridian in a given time will be to the arc of the equator, passed through in the same time, as 55 to 60.

Mr. Ferguson explains this subject by a very easy problem upon a common globe. If we put small patches of paper, or any mark we please, on every tenth or fifteenth degree both of the equator and the ecliptic, as inscribed on the globe, beginning at Aries ♈, and turn the globe gently round westward; we shall find all the patches or marks on the ecliptic from Aries to Cancer, come to the brazen meridian *sooner* than the corresponding marks on the equator; those from Cancer to Libra will come *later* to the meridian than the marks on the equator, those from Libra to Capricorn sooner; and lastly, those from Capricorn to Aries later again. The marks at the beginning of Aries, Cancer, Libra, and Capricorn, will come to the meridian at the same time with those on the equator; or the same thing may be proved by having two little balls to revolve in equal times, the one in the circle of the ecliptic, and the other in that of the equator.

3dly, The orbit of the earth being an ellipsis, of which the sun occupies one of the foci, the portions of the ecliptic which the sun appears to traverse are not equal to the portions which the earth really passes in its orbit.

These three causes combine at some times to produce the same effect; and at others they counteract each other. On these principles, what are called *equation tables* are calculated by astronomers, showing when the sun is faster or slower than the clock, or the difference between solar and mean time.

Solar time, from these circumstances, can coincide with mean time, only at four periods of the year, viz. the 14th of April, the 15th of June, the 30th of August, and the 23d of December. On all the other days of the year some inequality will be found, as shown by the equation tables.

We have seen that the day consists of twenty-four hours of mean time.—But the term *artificial* *day* is used to express the time while the sun is above the horizon; and the time during which the sun is below the horizon, is called *night*. The artificial day, it is well known, is of different duration in different regions of the globe, and at different seasons of the year. To those who live under the equator it is exactly twelve hours. At the poles the artificial day is of six months' duration; and at all those regions which lie between the equator and the poles, it is subject to considerable variations.

To these parts of the globe the artificial day is only of 12 hours length when the sun is in one of those points called the equinoxes, where the equator intersects the ecliptic. At other times, it is either longer or shorter, according to circumstances. To those who live between the equator and the north pole, the day becomes longer than 12 hours, in proportion as the sun continues to advance from the equator to the tropic of Cancer, that is, from the time of the vernal equinox; on the contrary, it becomes shorter than that period, in proportion as the sun advances from the equator towards the tropic of Capricorn, which takes place after the autumnal equinox. The contrary happens to the inhabitants of the southern hemisphere. Thus, in all the regions on either side of the equator there are only two days in the course of the year when the day and night are equal.

Such is the duration of the artificial day to the different inhabitants of the earth, if we regard only the actual presence of the sun above the horizon. But there is one cause, which serves to prolong the day-light, which we have not yet noticed, and that is refraction. After what you have heard in the optical lectures, you can scarcely be at a loss to understand its operation. From this cause the sun appears, both at rising and setting, above the horizon, when he is actually below it. Let us suppose (fig. 4.) T to be the earth, *t z* the mass of the atmosphere, S the sun just below the horizon H *h*; suppose the ray S *e* then to be emitted from that luminary, and to arrive at the atmosphere *e*, which must be of greater density than the medium through which the ray has hitherto been transmitted. The ray is consequently refracted towards the perpendicular *p p*, and reaches the spectator at *t*, who then sees the sun in the direction *t s*; he sees him, therefore, in a situation nearer the zenith than he really is.

But since the atmosphere is not every where of the same density, and since its density increases as it approaches the surface of the earth, the ray D *a*, for instance, must suffer many successive refractions, and arrive at the spectator *t* in a kind of curve *a b c t*; and if the line *t d* is the tangent to this curve, the observer will see the luminous body D elevated to *d*. The effect of refraction in our climate is to cause the sun, when he is in the horizon, to appear about 32 or

33 minutes of a degree higher than he really is; whence it follows that he will appear above the horizon when he is actually below it.

I have said that the *artificial day* comprehends all that space of time during which the sun is above the horizon; but if we apply this term to the duration of light, it must also include the *twilight*, and the length of the artificial day will be proportionably extended.

Twilight is that portion of light which the sun diffuses through the atmosphere before his rising and after his setting. The morning twilight, which the antients distinguished by the name of Aurora, introduces to us the dawn of morning when the sun is about 18 degrees below the horizon; and the evening twilight disappears when the sun has descended about 18 degrees lower than the horizon. Thus the line of twilight may be regarded as a circle parallel to the horizon, and about 18 degrees below it.

The morning twilight continues to augment as the day advances; that of the evening, on the contrary, decreases gradually till it totally disappears. I have said the twilight is the effect of the dispersion of the solar rays in the atmosphere, by which they are refracted and reflected in various directions. To understand this, let T (Pl. II. fig. 5.) be the earth, A A A the atmosphere, H H the horizon, C C C a vertical circle, which serves to measure the height of the sun, S the sun below the horizon either before his rising, or after his setting. The solar rays S *s*, S *s*, S *s*, S *s*, are directed towards the points B B B B, and they would pursue this direction but for the interposition of the atmosphere, which having more density than the medium through which they were last transmitted, and the rays coming in an oblique direction, they are refracted towards the perpendicular, and inclined o *t t t t*. As the sun descends, fewer rays reach the surface of the atmosphere, so as to take this direction. The twilight, therefore, gradually diminishes, and at last totally disappears in the manner already stated.

The duration of twilight is not the same at all places, nor even at the same place in all seasons; since, at certain places, and at certain times, the sun rises and descends perpendicularly from the horizon, while at others his motion both at rising and setting is more oblique, and the most so when his declination is the greatest, at which period it is plain that he must occupy more time in rising or descending a space which shall measure 18 degrees in the vertical direction.

The sun appears to traverse 15 degrees of the equator, or of some circle parallel to it, every hour; twilight therefore must endure for one hour and twelve minutes in those places where the sun rises or sets perpendicularly to the horizon, which is at the time of the equinoxes to those who live under the equator, or who have a right sphere. The length of twilight increases in proportion as the sun is further from the equator, or has more declination.

We must therefore conclude, that to those who live between the equator and one of the poles, or who have an oblique sphere, the length of the twilight must be greater in proportion as the pole is more elevated above the horizon, or in proportion as the place has a higher latitude. Thus, if the latitude is such that the sun at midnight on the 21st of June cannot have descended eighteen degrees below the horizon, as is the case in our climate, the evening twilight will not be finished before that of the morning commences; so that at this period of the year we have, properly speaking, in clear weather, no night at all.

It follows also, that if there were any inhabitants directly under the poles, who would, you know, have a parallel sphere, the twilight would be perceived by them two months before the sun appeared above their horizon, and would also endure two months after the disappearance of the sun. In a parallel sphere, therefore, there would not be more than two months of actually dark night; besides that, during these two months, the moon would be twice visible above the horizon for fourteen days at a time.

The astronomical day commences at noon of true time, that is, at the instant when the sun is in the meridian. In astronomy, the twenty-four hours of the day are counted from noon to the following noon again; so that instead of calling the hour after midnight one o'clock in the morning, as is called by the clock, it is termed the thirteenth hour of the day, and so on to the end of the twenty-four hours.

With respect to the civil day, its commencement has not been established by all nations at the same period. The Babylonians began to count the hours of the day from the rising of the sun. The Jews and Greeks, on the contrary, counted from his setting; and this, I believe, is the practice in Italy at present. All the other countries of Europe begin their day as we do, immediately after midnight.

In the Latin, the seven days of the week are denominated after the sun, moon, and the primary planets. With the exception of Saturday and Sunday, the French follow the same plan. In four of our days, Tuesday, Wednesday, Thursday, and Friday, we have adopted the names of four of the Saxon divinities, who are said to correspond with Mars, Mercury, Jupiter, and Venus; Saturday, Sunday, Monday, are the same as the Roman names.

Four weeks two days and about $\frac{7}{16}$th constitute a mean solar month, that is, the time in which the sun appears to traverse one sign, or twelfth part of the zodiac.

Twelve months constitute a year, or that period in which the earth completes her orbit round the sun, or in which the sun *appears* to have passed through the twelve signs of the zodiac. The year, therefore, consists of 365 days and about ¼. It was at first estimated at only 365 days. But as it was found that, while the earth makes a complete revolution in her orbit, she makes with respect to the sun 365 turns and nearly ¼ upon her own axis, which makes the year to include 365 days and six hours, and also that the equinoxes receded about the value of a day in every four years: to remedy this inconvenience, it was agreed to employ the six supernumerary or intercalary hours in giving an additional day to every fourth year, which on that account is called leap year, and contains 366 days.

The year, however, consists only of 365 days 5 hours 48 minutes and 45⅛ seconds. In adding, therefore, to every fourth year a whole day, we give 11 minutes and 14⅛ seconds too much. This quantity, though small in itself, must in the course of many years amount to a considerable sum. In the pontificate of Gregory XIII. the equinoxes had advanced ten days, so that the vernal equinox, instead of the 20th, fell on the 30th of March. This irregularity caused much inconvenience with respect to the festivals of the church. The pope, therefore, with the advice of the ablest astronomers, reformed the calendar. Having calculated that the surplus time, viz. eleven minutes and fourteen seconds, which had been added to the leap years, must amount to a whole day in 133 years, and that, consequently, from the time of the Nicene council, A.D. 325, the equinox had fallen back eleven days, they struck off at once eleven days from the current year, so that the vernal equinox then fell on the 21st of March; and it was further agreed to omit three of the leap years in the course of 400 years. This arrangement has already been put in practice; since the years 1700 and 1800, which would have been leap years in the usual course, were not observed as such. Even this plan is, however, not quite perfect, for, since the eleven minutes and fourteen seconds compose an entire day at the end of 128 years, instead of 133, this will still cause an error of one day in 3200 years, so that at the end of the year 4800 it will be again necessary to retrench another leap year.

LECTURE XXIV.

ASTRONOMY.

ECLIPSES.

In the 20th lecture I observed that, in a period somewhat shorter than a month, the moon was found once in conjunction, and once in opposition with the sun. In conjunction, when the moon is at N (Vol. i. Pl. XXVIII. fig. 119.) between the sun S, and the earth T; and in opposition, when the moon is at L, in such a situation that the earth T is between it and the sun. In the first case we should naturally expect that the moon would hide from us the light of the sun; and in the second, that the earth would prevent the sun's light from reaching the moon; and consequently, that every such occasion would produce an eclipse of one of those bodies. Notwithstanding this, we find the new and full moons but very seldom produce eclipses; and when they happen, it is not in the same proportions or in the same manner as you might expect on a cursory view of the figure.

If the moon's orbit was perfectly coincident with that of the earth, what we have been supposing would actually take place, and there would be a total eclipse at every new and full moon; but Providence has wisely ordered it better, and I think I shall be able in few words to explain the reasons to your satisfaction. The moon's orbit is inclined about five degrees to the plane of the ecliptic, or the orbit of the earth. When, therefore, the moon in the moment of her conjunction with the sun, happens to be in any point of her orbit a little distant from those points in which this orbit cuts the ecliptic, and which are called the nodes, there is sufficient latitude to admit of the light passing to the earth either above or below the moon, and there can therefore be no eclipse.—Or, when, in a similar case, the moon happens to be in opposition, the light of the sun will pass to her either above or below the earth, and the moon will not be eclipsed. But if the moon happens to be in the node, or very near it, at the time of her conjunction, she will then hide from us the light of the sun, and that luminary will be eclipsed: if, on the contrary, she happens to be in or near her node, while in opposition to the sun (being then in the plane of the earth's orbit), the earth will intercept from the moon the sun's light, and she will suffer an eclipse.

If you consider that it is only when the sun and moon happen to be in conjunction or opposition in or near one of the nodes that an eclipse can take place, you will see sufficient reason for the infrequency of the phænomenon. When, in fact, the sun and moon are more than seventeen degrees from either of the nodes at the time of conjunction, the moon is then too high or too low in her orbit for any part of her shadow to fall on the earth; and when the sun is more than twelve degrees from either of the nodes at the time of opposition, the moon is too high, or too low, to pass through any part of the earth's shadow. Her orbit contains 360 degrees; of which seventeen, the limit of the solar eclipses on either side of the nodes, and twelve, the limit of lunar eclipses, are but small portions; and as the sun passes by the nodes but twice in a year, it is no wonder that we have so many new and full moons without eclipses.

The eclipse of the moon then can only take place at its full, and when the moon is in opposition to the sun, and the moon is found either in one of his nodes, or near it. Suppose EE (Pl. III. fig. 6.) to be a portion of the ecliptic at the distance of the moon, along which the shadow of the earth is moving. This shadow is represented by the black circular spots ABCD, which may be conceived to be sections of the cone DCE in fig. 7, where S is the sun, and T the earth. Suppose again the line LL (fig. 6.) to be a portion of the orbit of the moon, which cuts the ecliptic EE in the point N, called the *node*, making with it an angle of a little more than five degrees. If, in the moment of her opposition, the moon is found in the point F in her orbit, she will be too far from her node, which is in N, and will have too much latitude to be able to reach the shadow. But if she is found in the point G, having less latitude, a portion of her disc will be plunged in the shadow. There will then be a partial eclipse, and if the moon is still nearer to her node, as at the point H, the greater the obscuration will necessarily be.

In short, if in the moment of opposition the moon is found precisely in her node N, the eclipse will not only be total, but central, and even will remain so for some time; for the center of the moon coincides with the axis of the conical shadow formed by the earth; and this conical shadow DEC (fig. 7.) occupying, in the orbit of the moon, a space FG, or *fg*, greater than the diameter of the moon L or M, it shades this planet for a time proportioned to the length by which the diameter of the shadow exceeds that of the moon, and this it is that causes the continuance of this planet in the shadow. The moon remains thus obscured the longest time when the sun S is in apogee, and the moon L in perigee; for then the conical shadow is the greatest that can be; and the moon being in the point L of her orbit, which is the nearest the earth, is found also traversing the shadow in the place where this shadow has the greatest diameter, FG, that the moon can reach; whereas, when the moon M is in apogee, she traverses the conical shadow nearer the summit C, and consequently in a place, *f g*, where the shadow is narrower.

When the moon is even totally eclipsed, she does not cease to be visible, for it is only the shadow of the earth which is cast upon her. She appears of a copper colour, or like a heated iron half extinguished. This effect arises from the scattered rays of light from the moon, which are refracted by the terrestrial atmosphere, and, crossing each other, afford a faint picture of the moon. This light is feeble, because it is small in quantity, and it is of a reddish colour, because only the red rays can penetrate our atmosphere in these circumstances. This is more obscure in proportion as the moon is nearer the earth at the time of the eclipse: there have even been eclipses when the moon has totally disappeared, but this is a rare phænomenon.

An eclipse of the sun can only take place when the moon is in conjunction with the sun, and when she is in one of her nodes, or very near it. Suppose the line EE (fig. 8.) to be a portion of the ecliptic, and LL a portion of the orbit of the moon, cutting the ecliptic in the point N, at an angle of a little more than five degrees. Then, if in the moment of her conjunction the moon is found in the point F of her orbit, she will be too far from her node to intercept the sun's light, and cause an eclipse. But if she is in the point G, having less latitude, she will hide a portion of the disc of the sun; and will then produce a partial eclipse, which would be still greater if the moon was nearer her node, as in the point H. In short, if, in the moment of the conjunction, the moon is precisely in her node N, the eclipse will be central; for the center of the moon, if viewed from that of the earth, will appear to coincide with the center of the sun. And if the apparent diameter AB (fig. 9.) of the sun S is greater than the apparent diameter QR of the moon L, it will form round the moon a ring, or a luminous crown; and the eclipse is then called *annular*. This ring of light will be larger in proportion to the difference between the apparent diameters of the sun and the moon. But if the apparent diameter ON (fig. 10.) of the moon L is equally great or greater than the apparent diameter BA of the sun S, he will appear entirely covered by the moon; the eclipse will then be total, and will endure so much longer as the apparent diameter of the moon shall exceed that of the sun.

For an eclipse of the sun to be annular, the case will be most favourable when the sun is in perigee, and the moon in apogee. And for an eclipse to be total, the most favourable case is when the sun is in apogee, and the moon in perigee.

The motion of the moon being swifter than that of the earth, and the motion of both being directed from west to east, that is, that of the moon from Q to R (fig. 9.), and from N to O (fig. 10.), and that of the sun from A to B, it will easily be seen that an eclipse of the sun must always begin in its western edge A.

As the moon is a great deal less than the earth, her shadow forms a cone NOC (fig. 10.) whose section is much less than the earth, so that only a small portion, DE, of the earth is involved in the shadow at one time. Hence it is that an eclipse of the sun is not perceived at the same instant in every part of the hemisphere which is thus turned towards the sun, and that in some parts it will not be seen at all. Moreover, in different situations, different parts of the sun's disc will appear eclipsed; for those who are in F see him eclipsed in the part IB, and those who are in G see him eclipsed in the part KA. On the contrary, an eclipse of the moon is perceived at the same moment in every part of the earth where this planet is visible, and appears every where to occupy the same portion of her disc. It is for this reason that eclipses of the sun are much less frequent in any particular place than eclipses of the moon.

If the moon's nodes constantly corresponded with the same points in the heavens, the eclipses, whether of the sun or the moon, would take place in the same months, and even on the same days; but as the nodes shift backwards, or contrary to the earth's annual motion about $19\frac{1}{3}$

degrees in the year, the same node will come round to the sun about 19 days sooner every year than in the preceding. From the time, therefore, when the ascending node passes by the sun, as seen from the earth, there will be only 173 days before the descending node passes by him. If, then, at any time of the year we have eclipses about either of the nodes, we may expect in about 173 days after to have eclipses about the other node*.

The nodes shift through all the signs and degrees of the ecliptic in eighteen years and 225 days; and in this time there would always be a regular return of eclipses, if any complete number of lunations were finished without a fraction. But this never happens; for if both the sun and moon should set out together from a line of conjunction with either of the nodes, in any point of the ecliptic, the sun would go through eighteen annual revolutions, and 222 degrees over, and the moon through 230 lunations and 85 degrees of the 231st, by the time the nodes came round to the same point of the ecliptic again; and therefore the sun would then be 138 degrees from the node, and the moon 85 degrees from the sun†.

After the sun, moon, and nodes, however, have been once in a line of conjunction, they will return nearly to the same state again in 223 mean lunations, or about eighteen years and ten days, so that the same node which was in conjunction with the sun and moon at the beginning of the first of these lunations, will be within less than half a degree of the line of conjunction with the sun and moon again, when the last of these lunations is completed. In that time, therefore, there will be a regular period of eclipses, or returns of the same eclipses, for many ages. But the falling back of the line of conjunction of the sun and moon, with respect to the line of the nodes in every period, will at length exhaust it, and after that it will not return again in less than 12,492 years*.

---

* Bonnycastle's Astronomy, lett. xxii. † Ibid.

If these principles are properly considered, it will not be difficult to conceive how astronomers are able to foretel the exact time when any phænomenon of this kind will happen. For, as an eclipse can only take place at the time of a new or full moon, the chief requisites are to determine the number of mean conjunctions and oppositions that will arrive in every year, and the true places of the sun and moon in their orbits at each of those times. And, if from this it appears that the two luminaries are within the proper limits of the node, there will be an eclipse, or otherwise not, agreeably to what has been already observed upon this subject†.

---

* Bonnycastle's Astronomy. † Ibid.

But in order to facilitate these operations, we have astronomical tables ready computed, by which the places of the heavenly bodies and every other necessary particular may be easily found for any given instant of time. Dr. Halley has also given a catalogue of all the eclipses that took place from the year 1701 to 1718, which the author of "L'Art de verifier les Dates," and others, have continued up to the year 1800.

In De Lalande's History of Astronomy for the Year 1800, it is asserted that M. Goudin has, by his analysis, fully determined the eclipse of 1847, the most considerable of the new century. That M. Duvancel, who has delineated eclipses for thirty years past, has likewise delineated this for every country on the globe. By his diagram it appears that it will be annular in England, France, Turkey, and even in Cochin-China.

In all eclipses, whether of the sun or moon, there are three points particularly to be observed, the beginning, the middle, and the end; and every precaution is taken to note the precise moment of each of these three phases. In total eclipses there are two other phases to be observed, these are the total immersion and the commencement of the emersion. In total eclipses, then, there are five phases to be observed, the commencement of the immersion, which is the commencement of the eclipse; the total immersion; the middle of the eclipse; the commencement of the emersion; and the total emersion, which is the end of the eclipse.

There is also another circumstance to be observed in every eclipse, namely, its greatness or extent, that is, the portion of the luminary eclipsed, or which is covered by the shadow. To measure this, the diameters of the sun and moon are supposed to be divided into twelve equal parts, which are called *digits;* and an eclipse is said to be so many digits, according to the number of those parts which are obscured. In total eclipses of the moon, it is often said to be eclipsed more than twelve digits, though the diameter of the moon is only estimated at that number. The expression then implies that the earth's shadow covers more than the disc of the full moon, and the shadow is measured as if it was a part of the luminary eclipsed.

The satellites of Jupiter are very frequently eclipsed. They revolve very rapidly round the planet; their orbit is very little inclined to that of Jupiter; and the mass of each of them very small, compared with his. It happens, therefore, that at each revolution they are necessarily plunged in the shadow of the planet, in other words, eclipsed. As it happens that these eclipses, from the great distance of Jupiter, can be perceived at different parts of the earth at the same instant, they afford a certain and very common method of ascertaining with exactness the difference of the meridians of these different places, and consequently their relative longitudes. There are two points to be principally attended to in the eclipses of Jupiter's satellites; viz. the immersion of the satellite in the shadow, and its emersion.

CHEMISTRY.

PL.V. VOL.II.

Fig. 11.

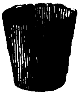


Fig. 12.

Fig. 13.

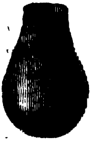


Fig. 14.

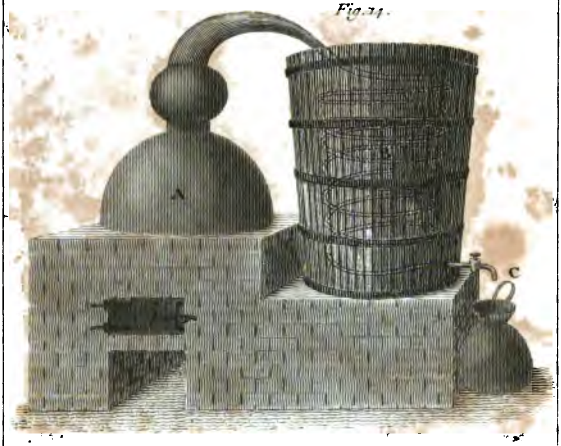
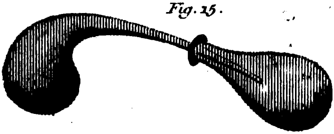


Fig. 15.



J.Farey Junr. del.

S.Porter sculp.

CHEMISTRY.

PL. VI. VOL. II.

Fig. 16.

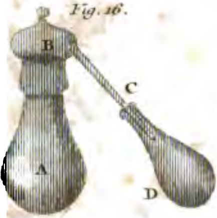


Fig. 27.

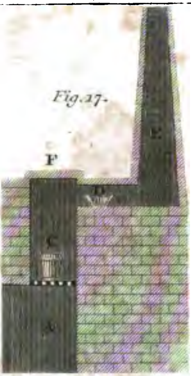


Fig. 18.

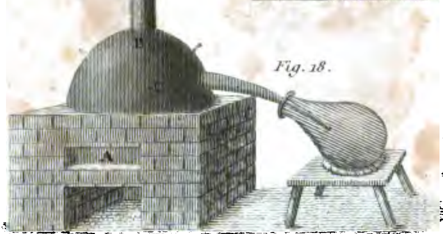
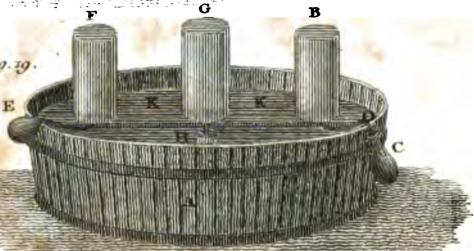


Fig. 19.



J. Farey Jun^r. del. S. Porter sculp.

LECTURE XXV.

CHEMISTRY.

GENERAL PRINCIPLES.

CHEMISTRY has been termed with some propriety the anatomy of *matter*; and its object is to discover the component parts of bodies, and, if necessary, to form them into new combinations. This last, indeed, is the principal occupation of the practical or trading chemist.

It is by the agency of heat and mixture, or, in other words, by the action of the particles of one body upon those of another, that the chemist is enabled to analyse or decompose the different substances which nature presents to his view. The matter of heat, or caloric, is the most powerful agent; for it has an attraction for most bodies, enters into their pores, and by its repulsive powers produces a decomposition of their constituent particles. There exists also in many cases a reciprocal attraction between the particles of one substance and those of another: this is seen particularly in all cases of *solution*; as when a lump of loaf sugar is put into a glass of water, it is said to be *dissolved*; that is, the particles of the sugar are intimately blended and united with those of the water by a mutual attraction.

Here let it be observed that mere mechanical *mixture* is very different from solution. A stone or an earth may be reduced to powder and mixed with water for a certain time, but the mixture will be muddy, and in a little time the solid particles will sink to the bottom; whereas if salt or sugar be dissolved in water, the compound will be always clear, and cannot be separated otherwise than by a chemical process.

These processes are generally by means of heat.—They are chiefly *evaporation*, or *sublimation*, which will be explained in the next lecture.

Fluid matters in which others are dissolved are called *menstrua*; and there is a certain limited quantity of the solid which they will dissolve or *take up* in solution by the power of attraction. Thus the quantity of salt which water will actually dissolve is limited, and whatever is beyond that will sink undissolved to the bottom. This point or limit is called the point of *saturation*.

Chemical attraction differs from the attraction of cohesion or aggregation in this, that it exists between the particles of bodies differing from each other, as between the salt and water; whereas the attraction of aggregation operates only between particles of the same kind. It is found also, that in chemical attraction the particles of certain bodies will be attracted by a given menstruum in preference to those of others. Thus sulphuric acid will dissolve a certain portion of copper, but if iron is added it will let fall the copper and take up the iron, and if an alkali is added it will drop the iron and unite with the alkali. The body thus let fall is said to be *precipitated*, and is called a *precipitate*, and the substance which is employed to cause its precipitation is called a *reagent*.

These observations may serve to afford a general idea of the effects of heat and mixture. In the remainder of this lecture I shall endeavour to give an outline of the principal doctrines of modern chemistry, and particularly with respect to the simple substances. I shall in the two following lectures proceed to point out more particularly the chemical effects of heat and mixture. I shall next describe the chemical apparatus or instruments; and shall then briefly examine and explain the nature and properties of mineral substances, salts, earths, metals, combustibles, and waters, as far as chemistry has made us acquainted with them; and lastly shall treat of vegetable and animal substances in the same manner, particularly as to the nature of their constituent parts.

It is one of the great uses of philosophy to make us better acquainted with an intelligent Providence, to show how wisely and with what infinite design all things in the heavens and on the earth are disposed; and every step we advance affords fresh cause for admiration. You have just been contemplating the wonders of the firmament. Those which modern chemistry displays to your view, though on a minuter scale, are not less striking. Can it fail to surprise any person capable of reflection, when he is told that the endless variety of created beings which nature presents to his view are composed from not more than forty-two simple substances; and that into the composition of the greater number not more than six or seven of these elementary substances are known to enter; for the metals and most of the earths are peculiar substances, and have little share in the formation of animals and vegetables.

Let it be observed, again, that chemical analysis has not yet probably proceeded all the lengths at which it may hereafter arrive; that many substances which at present we regard as simple, may hereafter be proved to be compound, and that possibly the ingenuity of man may never be able to reach the ultimate and elementary particles of bodies.

Those matters, however, which chemists have not as yet been able to decompose, they have a right to regard as simple substances. They are as follows:—

1 Caloric, or the matter of heat and fire*.

2 Oxygen.

---

* I am aware that chemists of high character account caloric and light as distinct substances, and of the curious experiment of Dr. Herschell on which this opinion is founded. But I have some objections to that experiment not proper to be stated here; and we know so little of the chemical properties of light, considering it even as a distinct substance, that its introduction at present would only confuse the student.

3 Nitrogen or azote.	
4 Hydrogen.	
5 Phosphorus. 6 Sulphur. 7 Carbon or Diamond.	Simple Combustibles.
8 The Muriatic Radical.	
9 Alkalies.	Potass and Soda.

10 Earths, of which there are nine in number.

11 Metals, in number about twenty-three.

I. CALORIC* or elementary fire. That this is a fluid of a peculiar kind can no longer be doubted, since it has all the properties of a fluid. It is perceptible to our senses only in a disengaged or active state; that is, in passing from one body to another. It is, however, diffused very copiously throughout nature. By its elastic quality it is the cause of all fluidity; and, indeed, was it not for the influence of this subtile fluid, the whole matter of the universe, there is reason to believe, would be condensed into a solid mass. Thus it is obvious that by withdrawing a certain portion of its natural heat from water, that fluid becomes a solid body and is converted into ice. Caloric might perhaps be termed the principle of repulsion, since it counteracts that of attraction, and seems to keep the particles even of solid bodies from adhering too closely; for an increase in the quantity of caloric, we see, expands even the most solid substances, such as metals. Yet we do not consider it as in a state of combination even when present in solid bodies, and still less when obvious to our senses as producing fire and heat. But it may fairly be considered as in a state of combination when its presence preserve a body in a fluid state even in the temperature of our atmosphere, such as water, quicksilver, &c.

---

* I adopt the term of the French chemists in preference to those of fire or heat, because these are properly effects, and because caloric is known to exist where neither of these effects is sensible. It seems indeed a kind of solecism to speak of latent *heat* in *cold* water.

A certain portion (or, in the chemical language, dose) of caloric reduces a body to the state of an incompressible fluid; a further dose brings it to the state of an aëriform or gaseous fluid. Thus a certain portion of caloric reduces ice to the state of water, a larger dose makes it volatile in the state of vapour.

Some bodies have a superior attraction for caloric in one state and some in another. Thus mercury will not part with its caloric and become solid till the temperature is reduced to 40° below 0.—Water will not part with it and become ice till the surrounding bodies are at 30°. But though water retains it obstinately in this state, and though it becomes vapour at 212°, yet it readily in this state parts with its caloric to any body colder than itself, and becomes water again. The gasses (or permanently elastic fluids) have however so strong an attraction for caloric in this state, that they will not part with it in the temperature of our atmosphere, or even at many degrees below our ordinary temperature.

Caloric combines readily with many of the simple substances.—With oxygen it forms oxygen gas—With hydrogen, hydrogen gas—With nitrogen, nitrogen or azotic gas—With sulphur, sulphurous gas. The metals and many of the earths it reduces to a fluid state.

It may then be laid down as a *canon* of chemistry. *That all fluids, whether incompressible or gaseous, are combinations of caloric with some other substance simple or compound.*

II. **Oxygen** is a matter which is never found in an uncombined state. It approaches nearest to purity in the state of oxygen gas (or combined only with caloric), which was formerly termed pure, vital or empyreal air, from its property of sustaining animal life and combustion.

Oxygen gas may be obtained by various easy processes. It may be procured by means of heat from all the oxides (or, as they were formerly called, calces) of metals; for it is the union of oxygen with the metals that reduces them to this calx, or cinder-like appearance. Thus red lead is an oxide or calx of lead produced by heating lead to a considerable degree in the open air, by which it attracts a quantity of oxygen from the atmosphere. The oxygen may again be extracted from the lead in the form of gas. To effect this, all that is necessary is to have a tub or vessel of water, with a shelf in it, on which a receiver may rest; a large tumbler will serve for a receiver. The tumbler must then be filled with water, and be reversed with its brim under water, and resting on the shelf. Put then some of the red lead with a small quantity of sulphuric acid into a phial bottle in which is fixed air-tight a bent tube*, which by an orifice in the wooden shelf may communicate with the receiver. Apply heat to the bottom of the phial, (that of a wax-taper or common candle will be sufficient) and after the common air which the bottle contained is expelled, the oxygen gas will rise in bubbles and fill the receiver or tumbler, displacing the water as it enters. The oxygen gas thus obtained is not the purest, for it contains some carbonic acid gas, which, however, may be extracted by bringing the mouth of the receiver in contact with some lime-water in a bason, and slightly agitating it, when the carbonic acid gas will be extracted by the attraction which the lime-water has for that substance.

Oxygen gas may be obtained in a still purer state by heating a small portion of the black oxide of manganese in a similar apparatus, only that as a stronger heat is required, the vessel containing the oxide should be of iron.

As it is possible I may not have explained myself sufficiently clearly in describing these experiments, and as some may be desirous of a more perfect apparatus, I shall beg leave to refer to (Pl. VI.) fig. 19, in the plate of chemical apparatus; where A represents the vessel or tub (sometimes filled with water, and sometimes with mercury); KKK the wooden shelf; B, G, F, are glass jars or receivers, inverted with their mouths downwards, and resting on the shelf. C is a glass bottle, which is supposed to contain the ingredients for furnishing the gas, and to the bottom of which heat is applied. D is a glass tube, generally fitted by grinding to the neck of the bottle, and curved so as to enter conveniently below the shelf, and communicate with the jar or receiver. E is a glass retort, which may be applied to the same purpose.

---

* The tube may be inserted into the cork.

Since oxygen is one of the component parts of water, any process that will decompose water will furnish it in the form of gas. Pump water, when exposed to the sun, will emit it in small quantities; and as all vegetables in a growing state decompose water, when there is a green slime (which is a vegetable matter) formed in water, in a bottle, &c. a quantity of oxygen gas will be separated when the water is exposed to the sun. Raw silk, and even very fine glass tubes, immersed in water, will also decompose it by means of the sun's heat, and produce oxygen gas.

Oxygen gas forms a considerable part of the air of our atmosphere, (about 28 parts in 100,) the rest is nitrogen, or azotic gas, which is not respirable, and will not support flame. On the contrary, oxygen gas is supposed to be that fluid which particularly supports animal life, by mixing with the blood in the lungs, to which it imparts the red colour; and by becoming condensed, it parts with its caloric, and furnishes us with animal heat; as is proved by every person who uses laborious exercise breathing quick, and becoming proportionably heated.

It also supports combustion. An iron wire, after being a little heated, and plunged in a vessel containing oxygen gas, will burn and flame like a candle. The oxygen, in this case, unites with the metal, and converts it into an oxide, or calx as it was formerly called from its being produced by burning, and resembling a calx or cinder.

Oxygen has indeed a strong attraction for all the simple combustibles, hydrogen, sulphur, phosphorus and carbon, forming different compounds. With hydrogen it forms water; with sulphur, sulphuric acid; with phosphorus, phosphoric acid; and with carbon, carbonic acid gas, formerly called fixed air.

It is usually in the state of gas that oxygen enters into combination with these matters. *Combustion* is the result of this union; for as in all these cases the oxygen gas at least is condensed, the caloric which retained it in the gaseous state is set free, and becomes sensible in the form of heat or flame.

It may therefore be established as a second canon of chemistry, *That all combustion is the result of oxygen gas uniting with some combustible body.*

To effect this union, the combustible bodies must be reduced to their ultimate or minutest particles. This is done by the application of heat, which also expands or removes the particles further from the sphere of each other's attraction, whence their union with oxygen gas is facilitated. Hence flame has been called ignited vapour; that is, it is the combustible body reduced to a vaporific form, and in that state combining with oxygen gas.

But one of the most extraordinary and important properties of oxygen is, that from which it derives its name. *Oxus,* in Greek, means sharp or acid; this substance, therefore, being considered as that which imparts the acid character to those bodies which are denominated *acids,* is called oxygen. Thus sulphur in its primitive state is one of the mildest substances in nature, but in combination with oxygen it forms that corrosive and dangerous fluid called sulphuric acid, formerly oil or spirit of vitriol. It is not, however, to every substance that oxygen imparts the acid character; for instance, with hydrogen it forms only water, which has none of the properties of an acid. The only substances to which it can impart the acid character are those which Lavoisier calls acidifiable or salifiable bases; of the simple substances these are, nitrogen, phosphorus, sulphur, carbon, the muriatic radical, together with a few of the earths and metals.

Oxygen, however, is not always combined in the same quantity with the same matter; whence a distinction is made by the modern chemists, marked by the terminations *ous* and *ic*. Thus sulphurous, nitrous, or phosphorous acid mean the substance combined with a smaller proportion of oxygen; and sulphuric, nitric, or phosphoric acid mean the combination carried to the highest point of saturation.

From this distinction with respect to the acids arises another, which relates to the compound salts into which they enter. Thus the compound salts formed by those acids which terminate in *ous* are marked by the termination *ite*. Thus we have sulphites, phosphites, &c. Those which result from a combination with the acids ending in *ic*, or the full or strong acid, are marked by the termination *at*. Thus we have sulphats, phosphats, &c. &c.

It may then be laid down as a third canon of chemistry, *That all acids are combinations of oxygen with some other substance.*

And it follows as a fourth canon, *That all compound salts are combinations of an acid with some other substance.*

Oxygen, we have also seen, combines with the metals, destroying the metallic lustre, and giving them an earthy appearance. This product was formerly called a calx, or cinder; but this term we now reject, because it implies that it is always the product of combustion, whereas oxides are produced equally by the solution of the metals in the acids, and afterwards precipitating them by an alkali.

Oxygen combines with the metals in different proportions, and these products are marked by modern chemists by the Greek numerals. The *protoxide* means the metal combined with the smallest portion of oxygen, *deutoxide* with a still larger portion, and *peroxide* the largest it is capable of receiving.

Some of the metals become oxidized by mere exposure to the damp and moisture: thus the rust which iron so readily contracts is an oxide of the metal, produced by its attracting the oxygen from air or water. In most cases, however, heat is necessary; and the perfect metals, as they were formerly called, gold, silver, and platinum, will not oxidize by heat alone, but require the agency of an acid, from which they may be precipitated by an alkali in the state of an oxide.

All oxides are heavier than the quantity of the metal which produced them in proportion to the quantity of oxygen with which they are combined.

III. Nitrogen derives its name from being the basis or constituent of the nitric acid. This is proved by an easy experiment. If a tube is inverted in mercury in the pneumatic apparatus (fig. 19.), and filled with thirteen parts of nitrogen gas and eighty-seven parts of oxygen gas, and an electric spark is made to pass through this mixture of the gasses, they will be condensed, and form pure nitric acid.

Nitrogen has not been made apparent to our senses otherwise than in a state of combination. The simplest form is that of a gas, or combined with caloric. In this state it forms about 78 parts in the 100 of our atmosphere, and is that part of the common air which will neither support flame nor animal life. On this last account it was formerly known by the name of azote* or *azotic* gas, because it was destructive of animal life. As it constitutes a part of the atmospheric air, and is incombustible, it is easily procured by abstracting that part of the air which is destroyed by combustion, viz. the oxygen gas. Thus, if a portion of iron filings and sulphur, moistened with water, is put into a vessel with common air, the oxygen will be absorbed, and will go to oxidize the metal and the sulphur, and the nitrogen gas will remain. The same effect will be produced by phosphorus alone, inclosed in a similar vessel with common air. The phosphorus will undergo a slow combustion, will be oxidized, or converted into phosphoric acid, and the nitrogen gas will remain behind.

---

* From the Greek privative *α* (*a* or *ab*, Latin), and *zoe*, life.

Nitrogen gas is considerably lighter than common air, and consequently much lighter than oxygen gas. Its specific gravity is to that of common air nearly as 942·6 to 1000.

It is immediately destructive of life if breathed without a mixture of oxygen gas; though it may be doubted whether the animal does not rather die from the want of oxygen gas than from any noxious quality in the nitrogen; since, when mixed with the former, every moment's experience convinces us that nitrogen gas is not only harmless, but even salutary. Its use in the atmosphere appears indeed to be to dilute the oxygen, and prevent its too violent effects on the animal frame.

Thus nitrogen unites with oxygen in two states; as in a state of mixture in atmospheric air, and in a state of chemical combination in the nitric acid. What is called the nitrous acid (common aquafortis) is the nitrogen combined with a smaller dose of oxygen. When this, or any of the acids, is stronger than usual, it is said, in chemical language, to be more *concentrated*.

Nitrogen gas extinguishes flame for the same reason that it extinguishes life, namely, from wanting that principle which supports both—oxygen. From this circumstance we may see the absurdity of the common practice when room or a house is set on fire, which is, to open all the doors and windows, by which a constant supply of fresh air is produced, so as to enable the fire to burn with greater violence.

In the gaseous form there are two other combinations of nitrogen with oxygen, which it is proper to notice from their singular properties. The first is that to which one of the first philosophers of the present day (Mr. Davy) has given the name of the nitrous oxide. It may be taken into the lungs by breathing, to a certain degree, with no dangerous consequences. But the effect is a momentary intoxication with exceedingly pleasurable sensations. The effects, however, cease in a very little time, and leave no sensation of languor behind, as in other cases of intoxication. The proportion of the ingredients is supposed to be about seven parts of oxygen to twelve of nitrogen.

The second is that which is called *nitrous gas*, and which is merely an unsaturated combination of nitrogen with oxygen. Hence it has a very strong attraction for oxygen, which it takes even from the atmospheric air. When brought into contact with common air, therefore, it rapidly absorbs the oxygen from it, forming nitric acid, and consequently destroys a certain portion of the mass. Hence it was employed as a test of the purity of air (more properly of the quantity of oxygen it contained), and an instrument was constructed called the eudiometer. This was only a glass tube, such as that exhibited in the pneumatic apparatus, fig. 19. In this was included a certain portion of any air which was meant to be tried; to this nitrous gas was admitted; and in proportion as the air in the tube was lessened (that is, in proportion to the diminution of the oxygen), the air was supposed to be more or less pure. Nitrous gas is estimated, from the experiments of Mr. Davy, to contain about fifty-seven parts in the hundred of oxygen, to forty-three of nitrogen.

IV. **Hydrogen**, as its name imports, is the basis or constituent of water, being derived from the Greek *hydor*, water. Because it is the constituent of water, however, it does not follow that this ingredient constitutes the largest proportion; for, in fact, water contains eighty-five parts of oxygen to fifteen of hydrogen.

Like oxygen, hydrogen is never found but in a state of combination; the nearest approach to a state of purity is that in which it is combined only with caloric, or in the form of hydrogen gas.

This gas was formerly known by the name of *inflammable air*, from its property of easily catching fire; from the same property it had long been known in the coal mines by the name of *fire damp*, where it rose spontaneously to the top of the mine; and if a lighted candle or other ignited body came in contact with it, it was presently in a blaze. It rises to the top of the mine from its great levity, being twelve times lighter than common air; and from the same property it has been employed for the inflating of air balloons.

Being a constituent part of water, whatever process decomposes water will produce hydrogen gas, provided the oxygen is absorbed by any matter, or otherwise disposed of. Thus, if water is dropped gradually through a gun-barrel made red hot in the middle, the water will be decomposed; the oxygen will form an oxide or rust with the iron, and the hydrogen will come out pure by a tube at the other end. The same effect is produced as often as a smith plunges a red hot iron in water. The hydrogen rises with the vapour, and is sensible to the smell, and the scales which fall off are oxide of iron. But the usual method of obtaining hydrogen gas is by pouring sulphuric acid diluted with water upon zinc or iron filings. In this case the metal is converted into an oxide, or rather a salt (sulphat of iron or zinc), which contains a superabundance of oxygen. Thus the watery fluid is decomposed, the oxygen entering into the composition of the salt, while the hydrogen flies off in the form of hydrogen gas. The same apparatus will answer for this experiment as that described above for the obtaining of oxygen gas.

If a phial is filled with this gas, and a candle is brought to its mouth, it will burn, as it rises by its levity out of the phial, till the whole is consumed. It is incapable, however, of supporting flame or combustion of itself; for if a lighted taper is plunged in a jar of hydrogen gas, it will immediately be extinguished. These phænomena admit of an easy explanation, on the principles already established. Hydrogen gas burns like other combustibles by its strong attraction for oxygen, with which it forms water, and both gasses being condensed, the caloric which kept them in the gaseous state is set free, and becomes sensible in the form of flame. The air of our atmosphere, you have seen, contains about twenty-eight parts in a hundred of oxygen gas, and while there is a fresh supply of it the hydrogen gas will continue to burn. Hydrogen gas, on the contrary, will not of itself support combustion, because the presence of oxygen gas is absolutely necessary to this effect, which is in this case the result of the union of these two gasses.

Hydrogen combines with the other simple combustibles, forming sulphurated hydrogen gas, phosphorized hydrogen gas, and carbonated hydrogen gas.

Hydrogen gas is not so pernicious when respired as some other of the gasses. If much diluted with common air, indeed, it may be breathed without injury.

V. PHOSPHORUS is one of those simple substances which we find in a solid form, though I do not know that it is any where found native;

all that is used in philosophy and commerce being obtained by an artificial process. As in the state of an acid it forms one of the constituent parts of bones, which are chiefly composed of phosphat of lime, it is easily driven off from burnt bones by a stronger acid. But the mode of obtaining it, and its most conspicuous properties, will be detailed more at large when we treat of combustible bodies. It is only necessary at present to mention it as a simple substance, and to notice its combinations.

Phosphorus, when pure in colour and substance, resembles bees-wax. Its most remarkable property is its very strong attraction for oxygen, from which circumstance it burns spontaneously in the open air at the temperature of 43°.—That is, in philosophical language, it attracts the oxygen gas from the atmosphere, which becoming condensed, heat and flame are produced. The consequence is, that the phosphorus becomes oxidized or converted into an acid. Phosphoric acid is heavier than the phosphorus which produced it in proportion to the quantity of oxygen which is combined with it.

Phosphorus combines with the other simple combustibles, as well as with many other bodies forming phosphurets.

VI. **Sulphur** is also one of those simple substances which is known to exist pure in a solid state. It is familiar to us under the old homely name of brimstone, and therefore requires no description. It is found combined with many mineral substances, as arsenic, antimony, copper, and most of the metallic ores, from which (being very volatile) it is easily driven off by heat, and collected in proper vessels. But I shall have to introduce more observations upon it under the class of Combustibles, and therefore have now only to remark its combinations.

Like phosphorus, it has a strong attraction for oxygen, and therefore is easily converted into an acid by combustion in the open air. A small dose of oxygen produces *sulphurous* acid, a larger portion *sulphuric* acid. The sulphuric acid (formerly called the vitriolic) is a very powerful agent in chemistry. But of its properties it will be necessary to treat under the class of acids.

Sulphur unites with the other simple combustibles, and some other bodies, and forms *sulphurets*.

VII. Carbon is certainly a substance very plentifully diffused throughout nature, since it enters into the composition of all vegetable and animal bodies. It is, however, only found pure and in a solid form in that most estimable of gems the diamond, which by various experiments is found to be pure carbon in a crystallized state. It is, however, found sufficiently pure for chemical purposes in the charcoal of wood, and will be treated of at large under the class of combustibles. I have at present only briefly to notice its combinations.

With oxygen, carbon forms carbonic acid, which is found naturally united with several substances. It exists in large quantities, united with chalk, limestone, marbles, &c. and in most mineral waters. It is not, however, to be obtained in a simple state by any process, and the purest is in that of carbonic acid gas, which was formerly known by the names of fixed and fixable air, from its uniting with chalk, lime, magnesia, &c. in a solid form. It was also called mephitic (or poisonous) air, from its destroying life when inspired into the lungs; and was long known to miners under the name of choke-damp.

Carbonic acid, united with the alkalies, lime, magnesia, and some other of the earths, reduces them to the state of *carbonats*, neutralizes them, and deprives them of their caustic (or burning) properties I shall have to add more upon this subject under the class of Acids.

With the other simple combustibles, and some other bodies, carbon unites, forming *carburets*.

VIII. Of the MURIATIC radical little is to be said, because it never has been found in an uncombined state. It has not been yet obtained even in the gaseous state uncombined with oxygen, so strong is its attraction for that substance. In that form, however, the muriatic acid is to be procured, and is termed *muriatic acid gas*.

The muriatic acid is the basis of common salt, hence called *muriat of soda.* It also combines with potass, ammonia, and many of the earths and metals, forming *muriats.*

It is capable of receiving a larger portion of oxygen than it naturally contains: with a certain portion it forms what is called *oxymuriatic acid*, and with still more *hyper-oxymuriatic acid.* The effects of these in bleaching is wonderful, as they destroy all vegetable colours whatever. But the subject will be properly treated under the head of Acids.

IX. The ALKALIES are properly only two, but are generally treated as being three in number. Two of them, *potass* and *soda*, are termed the *fixed* alkalies; because they do not rise or become volatile by heat: the third, *ammonia*, is called the *volatile* alkali, for the opposite reason.

Potass was formerly called the *vegetable* alkali, because it was obtained from the ashes of land vegetables, and was never found in a mineral state. Soda was called the mineral alkali, because it was found in some mines, especially in Egypt. That which is used in commerce is obtained from the ashes of certain marine plants, and is known in commerce under the name of barilla.

These two have been very lately decomposed by Professor Davy, and are found to be oxides of peculiar metals, the nature of which is, however, as yet but very little known; and they may (as to the metallic bases at least) be still classed among simple substances. The third, *ammonia*, has been long ascertained to be a compound of nitrogen and hydrogen; an account of it will therefore come properly under the class of Alkaline Salts, when some further observations will be introduced on the fixed alkalies.

X. XI. The earths and metals will require distinct lectures; and being substances of a peculiar character, and not entering so copiously into the composition of those bodies which are found on the surface of the earth as those I have been describing, any observations on their nature or combinations would be foreign to the object of this lecture.

I have thus endeavoured to lay before you a general outline of the doctrines of modern chemistry. I fear this lecture will appear uninteresting to many of you.—It is, however, of so much importance that, if it is well understood, it will greatly facilitate the study of all the remaining branches of this science. What follows will be rather a comment or elucidation of the contents of this lecture, and an application of its principles to practical purposes. I must therefore recommend your particular attention to it, and particularly to those leading principles, which I have ventured to term the canons of modern chemistry.

LECTURE XXVI.

CHEMISTRY.

THE CHEMICAL EFFECTS OF CALORIC; EXPANSION, FUSION, FLUIDITY, VAPOUR, AND COMBUSTION.

IT was necessary in the last lecture to give a general view of the properties of caloric. I fear I shall be thought in the present to be guilty of something like repetition; but it is necessary to the understanding of the effects of caloric as an agent in chemistry, to call your attention at present to the subject rather more in detail.

1st. The presence of caloric EXPANDS all bodies.

There are three forms under which matter can appear.

The first comprehends solid bodies, as iron, &c.; the second, unelastic or incompressible fluid bodies, as water, oil, spirit of wine, &c.; the third, elastic compressible fluids, as air. I shall now show the effects of caloric in expanding all these. If an iron or brass wire of about a quarter of an inch in thickness is cut so as when cold to fall just withinside, or short of two rings made to receive it, by rubbing it very hard with your hands or a piece of cloth it will be made warm, it will consequently be expanded, and lengthened so as to reach both rings, and be suspended in them while it remains warm.

If spirit of wine is contained in an oblong vessel, and immersed in hot water, the spirit will be observed to rise like the mercury in a thermometer.

A bladder, with a little air in it, when heated will expand so as almost to burst; but on removing it into the cold, it condenses and shrinks to its former state.

Rarer and lighter bodies expand more than the heavier and denser; but this proportion does not always exactly correspond to the respective density and rarity of matters; for metals expand more than glass.

As an exception to this doctrine it has been observed, that water suddenly swells in passing from a fluid to a solid state: but this is to be explained upon different principles. Boyle took a brass tube, three inches in diameter, and put some water into it; he then brought down into the tube a plug with a weight placed at the head of it of 74lb., exposing the tube to the cold, and the water freezing and expanding itself raised the 74lb. The Florentine academicians filled a brass globe with water, closing the orifice by a well-fitted screw, and immersed it in freezing water; but as the sides were too thick it did not burst. They then pared off such a quantity of the brass as left the sides of the globe unable to resist the expansion of the water, the force which was required to burst the globe in this state was computed at upwards of 27,000lbs.

Boyle says, the expansion of water in freezing is about an 8th or 9th of its bulk. The bursting of leaden pipes placed near or within the earth's surface proceeds from the same cause. The pavement even suffers from the frost, which swells the earth and loosens the stones; nay, rocks have been known to burst in frosty weather. Frost is by some supposed to fertilize, by loosening the cohesion of the particles of earth.

As ice is never clear or transparent, and as we find several cavities in it, some have thought that the air insinuates itself, and in this way have endeavoured to account for the expansion. But this has been refuted by water being frozen under an exhausted receiver, and the same cavities being found in the ice; the ice, indeed, instead of being heavier, was lighter, and floated on the water. M. D. Mairan at length solved the difficulty. He says, the particles of water in freezing assume a different arrangement, are not in so close contact, and cut each other at angles of 60°. If this is the case, then, as indeed is now generally agreed, we cannot say with propriety that the solid particles of water expand, but that from their crystallization into the form of ice they require more room, or occupy a greater space.

As salts are observed in crystallization to put on regular figures, it was thought that the star-like appearance of snow was owing to a salt mixed with the water; but Margraff proved that snow is in fact composed of the purest water.

Reaumur observes that cast iron melted in passing from a hot to a cold state expands. This effect is more sensible in this than in any other of the metals, on account of its platey texture. He found also that cast iron thrown among some of the same metal in a melted state swims upon the top. In this case of immediate expansion upon congealing, the iron seems to agree with water. But they differ in this, that the iron never expands by cold afterwards, whereas the ice being exposed to greater degrees of cold becomes still more bulky; the solid parts not being so closely connected form a particular arrangement, which renders the whole mass specifically lighter than before.

Denser bodies for the most part expand less than rarer; but this I observed is not an invariable rule, for metals expand more than glass or stones. The expansion of metals was found a great obstruction to the regular going of clocks, but is obviated now by the ingenious contrivance of making use of two different metals, which do not expand equally, in constructing the pendulums.

Of the three classes of bodies which compose the universe, solid bodies suffer the least expansion from the presence of caloric. Liquids are more expansible than solids; and aëriform fluids are most expansible of all. By the accurate experiments of Mr. Dalton of Manchester, it was found that all gasses, or aëriform fluids, undergo the same expansion by the same degrees of heat, supposing the circumstances the same. It may be useful to note, that he found by his experiments that 100 parts of air by being heated from 55° to 212° expanded to 132¼. The steam of water and the vapour of ether undergo the same expansion with air when the same addition is made to their temperature: hence all elastic fluids may be said to expand equally and uniformly by heat.

What is remarkable, bodies, though expanded by caloric, never suffer any increase of weight from its presence. Muschenbroeck says that iron when heated loses 1-100th of a grain in the cubic inch, and the same quantity of lead loses 4 grains, but when cool they return to their former weight. This loss of weight, however, is rather owing to the rarefaction of the air round the scale; the pressure of the atmosphere on the scale being lessened, the metal weighs lighter; the heat might also expand the side of the beam, and render it false.

When we speak of the specific gravity of bodies, we ought to mention the degrees of heat; for the specific gravity is different in winter and in summer, and this is owing to the expansion of the body by the presence of a larger quantity of caloric. Boerhaave supposes that air, which is the lightest body, might be made to assume the density of gold.

In the second place, I have to notice the distribution of caloric or heat. That substances, when heated above the temperature of those bodies which surround them (a bar of iron for instance), soon part with their superfluous caloric (in other words cool) is well known: and in like manner a cold body introduced into a warm place soon acquires the temperature of that place. The distribution of heat is more rapid in proportion to the contact of parts; hence the excessive slowness with which heat is communicated to those bodies which are rare and spongy, and hence its celerity in hard bodies. If a rod of iron is put into the fire for a little time, the end which is at a good distance from the fire will almost burn the hand, but a stick will be burnt to ashes before the other end is heated. We find caloric greatly retarded by cork, and still more by feathers and wool. Hence arises the distinction of good and bad conductors;—the iron is a better conductor of caloric than the wood, and the wood is still better than cork or feathers. The difference in the cooling of hot bodies depends much upon their goodness as conductors. When mercury and water, each heated to the same degree, are placed in similar circumstances, the mercury cools twice as fast as the water. Straw, flannel, and feather-beds are considered as warm; but they have no heat in themselves, for they keep in fact any body cool better than other substances, as ice in ice-houses is kept under straw.

These bodies hinder the caloric from escaping, their interstices being filled with air, which is the rarest of fluids. Snow keeps the ground warm also, from its being of a soft and spongy texture. It is true it cannot keep the ground warmer than the freezing point, but this is warm when compared with the intense cold felt in several climates, frequently 32° below frost; the freezing point being as much warmer than this, as our summer weather is hotter than frost.

Fluids convey heat very readily. Air cools bodies extremely fast. This, however, may depend upon the expansibility of air when heated, which will produce the effects of a constant change. Thus, if I expose a hot body to the air to cool, the air that is in contact with it expands and becomes lighter, consequently is driven upwards; and thus there is a constant succession of cold air applied to the body: and if we place the heated body between the sunshine and a wall, we shall see the rarefied vapour rising like an undulating smoke upon the wall. The reason why we see it is, because the rays of light which pass through these steams are turned aside; by this means the wall is less illuminated in this part than the rest, and therefore we see the shadow: for the same reason that we see the shadow of smoke. This circumstance makes objects seem to change place and tremble, when viewed through the rarefied atmosphere of a heated field when the sun shines upon it; the fluid contained in the earth and plants constantly evaporating, and the vapours having a tendency upwards. It is owing to this tendency upwards that iron or any other body will heat a body held over it sooner than under it. Hence the cold observed at sea upon approaching mountains of ice: the cold air being condensed falls down the sides of the ice and floats along the surface of the sea. A vessel of water being placed over the fire, the heat expands and renders lighter the bottom of the water, which of course ascends to the top, while another part, denser and colder, falls to the bottom; and thus there is a constant circulation from the under to the upper part of the vessel. When we have occasion to heat glass all over it is very apt to break, if the fire is not equally applied. For this end we immerse the vessel in water, using the operation of the balneum mariæ, as it is improperly called.

From the nature of fluids, deep lakes of water do not freeze in the winter: the cold air rushing over the surface, a portion of the water at the top being thus rendered heavier will sink, and its place be supplied with a warmer portion from below, which in its turn must also be cooled. Thus the cold air has the whole heat of the water to carry away, which is frequently not done during a winter. Hence the equal temperature upon the ocean and upon islands, when compared with continents in the same degree of latitude.

But the equal distribution of caloric or heat does not seem to agree with some phænomena which frequently occur. The highest parts of the air are the coldest, and the contrary. On the Alps, Pyrenean mountains, &c., the ice and snow are higher than the clouds, and seem to increase: and we are further convinced of the cold of the superior parts of the atmosphere by showers of hail which fall in the summer.

This distribution of heat has been explained in different ways; but the real principle is as follows: It appears that the sun is the source of heat to this globe, and we must observe that the rays of the sun do not heat a body that is perfectly transparent. When the body is not perfectly transparent, and reflects some few of the rays, it is somewhat heated, though nothing in comparison with opake bodies. Hence black bodies are soonest heated. If a burning glass is so placed that the focus falls a little below the surface of a transparent water, it does not heat the water: if then you plunge a stick into that part of the water, it will be immediately burnt to a coal in its interior parts, the surrounding water preserving the exterior ones. The rays of the sun, therefore, not heating transparent bodies, they have little effect upon the air; but the upper part is more transparent than the under, and the lower parts receive almost all their heat in a secondary manner by reflection from the earth. But it still remains to show why the lowest part continues warmest, and does not rise, as in the other fluids. This fact was partly explained in a former lecture. Air is a fluid very different from water, it is very compressible. The atmosphere may be supposed to be composed of very eccentric layers, the lowest layer being the densest. The lower strata, then, are rarefied a little by heat, but are compressed by the superior; and the heat is preserved by this compression of the superior air on the surface of the earth, where it is intended to act.

The coldness of the air seems to condense the vapours, and causes them to fall in showers, upon which the life of vegetables depends. This shows the use of planting the superior parts of a country. As green-houses made of glass receive the heat transmitted through it, but confine the air when heated; so, on the contrary, the ground that is quite exposed and naked has its heat so quickly carried away by scorching winds that it is rendered barren.

3dly. FLUIDITY, as was formerly mentioned, is one of the most general effects of heat. Not only solid bodies, we find, may be rendered fluid by heat alone, but even those bodies which generally appear fluid, owe their fluidity to the caloric they contain, which being sufficiently diminished, they become solid. It is somewhat remarkable that mixtures of bodies generally melt more easily than the bodies by themselves; of this we have an instance in metals; but this is only an increase of the disposition to fluidity, which depends upon caloric at last. Some bodies require the most intense cold for their congelation, the smallest is sufficient to freeze others. Before Professor Braun, it was thought that mercury was not to be frozen.

The only parts of matter that have shown a repugnancy to become fluid are some earths and stones, but these are few in number, and the number has still been diminished since the application of burning-glasses. Those bodies which cannot melt by themselves, melt in mixture with others; we may therefore reasonably conclude they would become fluid, if we could apply a sufficient degree of heat, and in a proper manner.

There is this difference between expansion and fluidity, that in expansion there is a regular increase and contraction of bulk, according to the degree of heat; whereas in fluidity the transition from a fluid to a solid state, or the contrary, is sudden, and below or above a particular point of heat a body always remains fluid or solid. There are, however, some bodies which appear in an intermediate state of fluidity, as wax, sulphur, pitch, tallow, &c.; yet every particular degree of softness depends upon a particular degree of heat, and the point at which they become fluid is still a settled one.

This point is called their melting point, which in the undermentioned substances is as follows:

Lead -	594°	Milk -	30°
Bismuth	576	Vinegar -	28
Tin -	442	Blood -	25
Sulphur	212	Oil of Bergamot	23
Wax -	142	Wines -	20
Spermaceti	133	Oil of turpentine	14
Phosphorus	100	Sulphuric acid	36 below 0
Tallow -	92	Mercury -	39
Oil of anise	50	Liquid ammonia	46
Olive oil -	36	Ether -	46
Ice - -	32	Nitric acid	66

In general those solid bodies which crystallize have no interval between solidity and fluidity, while those which do not assume the crystallized form exhibit that gradual softening which I just now remarked.

Some bodies, after having appeared in a fluid state by means of heat, concrete again into the same form as before they were melted, as salt, ice, the metals, especially gold and silver; the melting of these bodies is called *fusion*. There are other bodies, as earths, stones, oxides of metals, which suffer alteration and concrete into masses like glass, of a hard and brittle nature, and whose particles, when broken, have hard and polished surfaces. The making of this glassy concretion is called *vitrification*. When these masses are mixed with metals we apply the name of *scoriæ*; but if these bodies are melted over again, they always appear under the same form of glass or scoriæ as before.

Fluidity has hitherto been considered as depending upon the quantity of sensible or obvious heat; but though it may render the subject rather complex, we shall find there is something else to be attended to. From facts and experiments it is proved that fluidity does not depend upon the *sensible heat*, or that which we perceive in bodies by our senses, and the thermometer, but upon a certain quantity of what Dr. Black called latent heat, imperceptible to us, but ready to emerge on proper occasions, and assume a sensible form. I mean by obvious or sensible heat, that which is so far in a fluctuating state, that if you apply any body which contains an excess of it to a cooler one, it immediately leaves the hotter, and flies to the cooler body, so as to restore an equilibrium. This will be the case of all bodies which are conductors of caloric or heat, and in proportion to their conducting power, while they do not change their state; but when they are about to change, their temperature or sensible heat is not increased, for the caloric is absorbed, and, instead of being sensible, serves to render them fluid. Thus ice conducts caloric at any degree below the freezing point, and a sensible increase of the temperature may be observed in it till it reaches that point, viz. 32°; but when it has attained that degree it will remain at or near it till the whole is melted.

The reason is clear, that when arrived at this point, the body is in a state for the absorption of caloric, which process goes on without any increase of temperature till the whole is rendered fluid. In proof, I shall instance the slowness with which ice and snow melt. When a thaw comes on when the heat is far above the degree of frost, though the ice is constantly surrounded by air warmer than itself, and constantly receiving heat from it, yet it will be hours, sometimes days, in dissolving. If nothing was necessary to produce fluidity but mere sensible heat, we might expect, that after it begins to melt a short time would be sufficient to melt the whole; but since it is so long in dissolving, and its heat is not increased above the freezing point, nor the water that runs from it above thirty-two or thirty-three degrees, this obvious heat, or, in more philosophical terms, this excess of caloric, to which it is exposed must be absorbed, and become latent. It is owing to this that ice can be preserved in ice-houses, and that large masses of ice and snow remain at the tops of mountains whose heat is considerably above the freezing point.

If, on the other hand, we expose water to freeze, and put a thermometer into it, at first suppose it is twenty degrees warmer than the cold air, it will lose a great many degrees during the first five minutes, less the next, and so on; in half an hour (if the temperature of the air is below frost) it will have arrived at that temperature, and we should expect that in two or three minutes all of it would be frozen, if it depended only upon a diminution of sensible heat; but this is not the case, for we find at first a small part of it freezing, and gradually increasing in the congelation. All this time the water continues at thirty-two degrees, which is perhaps one or two above the temperature of the air to which it is exposed. Now since it is known that if a colder body is applied to a warmer it will soon become of the same temperature, what prevents the water from becoming of the same temperature with the air to which it is exposed? It is doubtless owing to the caloric, which had been latent, emerging and becoming obvious or sensible as soon any particle of the water freezes, and as soon as this is all exhausted, the mass becomes solid and of the same temperature with the air. The quantity of caloric which thus emerges when a fluid body passes into a solid state might be estimated, if the temperature of the air would continue the same for a sufficient length of time. From all this it is plain that the combination of a certain portion (or dose in the chemical language) of caloric with ice, turns it into water, and the removing or taking away of that portion of caloric converts it again into ice. Thus water is a compound of ice and of caloric; and indeed all fluids (according to the first canon of chemistry) are combinations of the solid, and a certain dose of caloric. The quantity of caloric necessary to render ice at 32° fluid is 140°.

There were disputes in Fahrenheit's time about the rarefaction of ice, whether it depended on the air contained in it during its fluidity. He imagined that if he extracted the air from water, he could produce an ice heavier than water. He extracted, therefore, the air from small glass globes filled with water, and after exposing them to an intense cold, they were a long time in freezing, though cooled greatly below the freezing point; but upon breaking them to examine them, the air rushed in, which, from the sudden shock, occasioned the water to freeze in a moment.

He afterwards found that simple agitation had the same effect. If water is set at rest, it may be cooled several degrees, as seven, eight, nine, or ten, below the freezing point, without being congealed; but if touched with a bit of ice, or the end of a wire, or if the vessel is agitated, the congelation pervades it like a flash of lightning. This is confirmed by Mairan in his treatise of frost. He exposed small drinking-glasses full of water, which might be cooled below the freezing point, and if left undisturbed, might remain so, but upon being agitated they froze immediately; and if a thermometer was put to the water during its freezing, the moment it was frozen it rose up to the congealing point; therefore a quantity of latent caloric seems to have quitted the water: only part of the water was congealed into a spongy substance, which contained water in its pores; the water was eight or nine degrees below frost, and suddenly became warmer. Here we see a quantity of latent caloric suddenly emerges. These experiments not only prove the existence of latent caloric before the water freezes, but likewise that the freezing does not depend on the diminution of sensible heat, since we find it may retain its fluidity, though cooled eight degrees below the freezing point: nor does it depend merely on its tranquillity; for, if it did, we should expect, upon disturbing it, that the whole would be congealed: this does not happen; and the reason is, that a quantity of latent caloric is impelled inwards, which raises the temperature above thirty-two degrees, below which it must fall before it can be frozen. In the ordinary freezing of water something happens like this, though by insensible degrees; when water is exposed to freeze, before the whole of it is converted into ice, it must all the time be imparting heat to the air.

Several facts and phænomena are explained upon this principle, as the production of cold by a mixture of ice with the nitric acid or saline substances. If the nitric acid is mixed with ice or snow, there will be a sudden liquefaction; consequently a sudden absorption of caloric, which will produce a degree of cold in the surrounding region.

Mixture in general promotes liquefaction. In this instance a most intense cold is produced, and the cause is as follows: If I can liquefy ice, I know I must throw in a prodigious quantity of obvious heat or caloric, and which must immediately become latent in the liquid, and hence it is not discoverable by a thermometer. By producing a sudden liquefaction of ice, the cold is so great that all the neighbouring bodies must supply or communicate from their obvious heat the caloric that is to become latent in this liquefaction, and to restore the equilibrium; and thus it proves in this experiment. If I pour a quantity of nitric acid upon ice, it immediately liquefies, and produces a great increase of cold. This is no other than the obvious heat turned into the latent, to supply the newly produced fluid. This experiment is just the contrary of that where you have water cooled some degrees below the freezing point, and if it is at rest it does not freeze; but if you shake the glass you make a portion of it freeze: this, on becoming solid, parts with its latent caloric, which becomes obvious, and by its means the water which has not frozen has its temperature raised.

The fourth general effect of heat is the formation of VAPOUR. By vapour I mean a transparent fluid, which, like air, is compressible and very elastic, and which suffers great alteration in its bulk from considerable accessions of heat. If a drop of water is placed on the bottom of an exhausted receiver, it will suddenly disappear, and be converted into a subtile vapour which will fill the vessel; and its pressure against the internal surface will be so strong when heated to a certain degree, that it will be almost impossible to confine it, and it will often burst the vessel with a loud explosion. This effect of the force of vapour is sufficiently exemplified by the small pieces of glass called candle balls, which burst by the expansion of the vapour. This great expansion of the vapour is the true cause of the danger of throwing water into boiling oils or melted metals, especially brass or copper. The water being a heavier fluid than the oil falls to the bottom, where it is immediately converted into vapour, and causes a violent ebullition. A small quantity of humidity when mixed with hot metals, will be converted into vapour with such rapidity as to produce a more violent explosion than gunpowder. Hence the danger of casting copper or iron vessels; for, if the fluid metal meets with the least moisture in its passage from the furnace to the mould, the watery particles are instantly expanded, and throw the burning metal to a considerable distance. Vapour, when condensed, resumes its former state; and upon these principles, viz. the elasticity and condensibility of vapour, depends the construction of the steam-engine, as was formerly explained.

To compare the weight of steam or vapour with that of water, place a flask with a small quantity of water in it before the fire; the moment the whole of the water is converted into vapour, close the vessel, and it will then be filled with steam. Weigh the vessel thus filled with steam, weigh it again filled with air, and lastly filled with water. This will give you the weight of steam compared with that of water, which is in the proportion of about 1664 to 1.

The point at which a fluid is converted into vapour depends upon a certain degree of heat, and this we call the vaporific or boiling point, which differs widely in different bodies. The terms *volatility* and *fixedness* are only terms of comparison. Thus, when we say a body is volatile, we only mean that it requires less heat to convert it into vapour than most other bodies; and by a contrary reason we define bodies fixed. The vaporific point is always the same in the same bodies. It agrees in this with the effect of heat in producing fluidity, but the vaporific point is remarkably influenced by mechanical pressure. The greater the pressure, the greater the degree of heat necessary to convert the fluid into vapour. Fahrenheit, by the barometer, observed that according to the greater or less pressure of the atmosphere, a fluid required a greater or less degree of heat to convert it into vapour; he marked the vaporific point of water on his thermometer at the mean height 212. If water, however, can be prevented from going off in steam, as it may by means of a particular contrivance, it will acquire a degree of heat equal to that of metals when red-hot. The machine for this purpose is called Papin's Digester, and is a copper vessel half filled with water, the head screwed in and well luted: when the water is so hot as to send off vapour, its escape is prevented by means of a weight and lever across the lid, which confine it in proportion to the increased pressure of the vapour. The water by these means acquires a degree of heat, which Muschenbroek says he found sufficient to melt lead or tin. Bones have by these means been totally dissolved in water, and reduced to their constituent parts, nothing remaining but earth or ashes, which may be easily crumbled between the fingers.

As the vaporific point is always the same under the same pressure, we may consider it as always the same in the open air; at least it does not vary more than three degrees. It is a matter of curiosity to examine the difference of the vaporific point of any liquor under the exhausted receiver, and when exposed to the pressure of the atmosphere. It is found that water boils in vacuo at ninety degrees.

When a single drop of water is heated to its vaporific point it immediately becomes vapour; but if the quantity is more considerable, the phænomenon will be varied. For, if a quantity of water is thrown into an iron vessel heated red-hot, it will seem to run about the vessel like quicksilver, but without touching the bottom or sides of the vessel. The reason is, the water nearest the bottom and sides is converted into vapour, which prevents the water coming into contact with the vessel. This is the reason, too, that a lump of iron dropped into water continues red-hot for some little time, for the water nearest the iron being instantly converted into elastic vapour, keeps off the rest of the fluid.

Water does not become hotter by being boiled long. This phænomenon has been variously accounted for: some supposed that water will not contain above a certain quantity of heat; the additional heat, they say, bursts through the fluid, and gives it a bubbling motion. Others have supposed that the air contained in the water becomes elastic by the heat, and forces it's way through the fluid. Neither of these theories is, however, satisfactory; but the true explanation is easy. In the common way of boiling water, the bottom of the fluid arriving at that point of heat, beyond which it cannot continue without being converted into vapour, is thrown up in vapour to the surface, and this occasions the violent ebullition observed there. Thus the quantity of water is diminished, while its heat is not, and cannot be, increased; for, after the fluid has been raised to its boiling point, the continued application of heat converts it into vapour, but does not make it hotter. In this conversion of water into vapour, it will be found by some experiments that the caloric applied to the water disappears, and becomes latent in the vapour.

The degree of sensible heat is only necessary as a condition, but is not the immediate cause of the conversion of a fluid into vapour. If we observe the heating of water in a furnace, we shall find that the heat flows into it very fast till it arrives at the boiling or vaporific point. Suppose in the last five minutes its heat is increased ten degrees, in the next five we should imagine it would be at least six or seven degrees more, and that this would be sufficient to convert the whole into vapour; and it would be so if nothing more was requisite for this effect than sensible heat: but this is, not the case, for in reality very little of the water is evaporated, and the remainder is not sensibly hotter.

Water more easily or with less heat boils in vacuo than under the pressure of the atmosphere (viz. at ninety or ninety-five degrees); but to convert it all suddenly into vapour requires as much or more fuel than in the common way over an open fire can be applied to it.

Boyle placed some warm water, which he had previously boiled, to extract its air under an exhausted receiver. On applying heat, the water boiled violently at a degree of heat not much above that of the human blood. Dr. Cullen also placed ether under the receiver of an air-pump, into which he could let down or raise a thermometer at pleasure, without admitting the external air. He no sooner began to extract the air than the ether was thrown into a violent agitation or boiling, at the same time its temperature sunk to a surprising degree. When the ether was first put in, it was about fifty-eight degrees, but it became so cold when boiling, that a quantity of water in a surrounding vessel was suddenly frozen. The manner the phænomenon is to be accounted for is this: the weight of the atmosphere being removed, the caloric the ether contained was sufficient to make it boil. The heat that disappeared, or, in other words, the cold that was produced, while the ether was boiling is easily accounted for. The boiling of the ether, like the boiling of water, arose from the conversion of the fluid into a vapour more subtile than itself; but the conversion could not take place without the absorption of a considerable quantity of caloric, that is, much of the sensible heat of the fluid became latent in vapour. Now it is well known that water and spirit of wine boil in vacuo 122 degrees below their boiling point under the pressure of the atmosphere. It is natural, therefore, for ether, which boils in the open air, when heated to about the heat of the human blood, to boil in vacuo twenty-four degrees below 0, which is a degree of cold sufficient to freeze any water that may be in contact with the vessel which contains the ether.

This experiment ought to be attended to, because it is a clear proof that the sudden diminution of heat is not always occasioned by its being taken away by the surrounding matter.

This evaporation at low temperatures is not confined to liquids; many solids are also susceptible of it without previously passing through the fluid state, of which camphor and carbonate of ammonia are familiar examples. These very substances, however, as well as others which have been supposed incapable of liquefaction from their volatility, are, in the common processes for purifying them, reduded to the liquid state, and even made to boil in vessels freely communicating with the external air.

Hence may be understood the nature of several chemical operations, as *evaporation*, *distillation*, and *sublimation*. These processes are performed on bodies composed of different ingredients, some of which are more easily volatilized than others. The most volatile will be first converted into vapour. If we take a mass of clay, water, and quicksilver, if we expose this mass to heat, the water will first rise in vapour, and be entirely expelled before the mercury begins to rise, and this vapour may be condensed into pure water. By increasing the heat the quicksilver will rise also, and leave the clay by itself. The process is called *evaporation*, and is used when we wish to obtain the more fixed parts, and are not solicitous about the volatile, as in the making of salt. When the volatile parts are the object, the process is called either *distillation* or *sublimation*; the former when the vapours condense into fluids, the latter into solids. The product of sublimation is called *sublimate*, when it is close and compact; it is called *flowers* when its texture is loose like soot.

Animal and vegetable substances are composed of various ingredients, which may be separated by the application of heat. But heat operates upon them in a different manner from what it does on other substances. If a piece of flesh is exposed to heat, it is not like iron expanded, but on the contrary is contracted; for the humid parts fly off, and leave only the fixed or denser parts behind.

Heat applied to animal substances does not convert them into a vapour that may be condensed into any substance of the same kind, but into oil, water, charcoal, and some saline substances. When the volatile parts are evaporated, the remainder has a different arrangement from what it had before.

It may seem rash to assert that heat has a power of bringing into fusion and volatilization all bodies without exception, as we have not sufficient data or experiments to render this opinion absolutely certain; for all those earthy substances that have been rendered fluid have not as yet been converted into vapour, and there are some earthy substances that have not even been brought into fusion.

Some metals, especially gold and silver, were once thought to be absolutely fixed. Boyle took a small quantity of each, and exposed them for two months to a glass-house furnace, and at the end of this time he found them not altered. They have since, however, been brought to emit very sensible vapours from the more intense heat of a burning-glass. Hence we have some reason to conclude, that with sufficient heat the earthy substances also might be fused and volatilized.

V. The last of the more general effects of caloric is COMBUSTION; but this effect is not so general as the former, since there is only one class of bodies susceptible of it, hence called combustible bodies.

The distinction between them and others is, that the bodies which are not combustible are not altered by heat in a permanent manner, nor is the caloric which they receive at all increased, but is readily transmitted. Combustible bodies, on the contrary, are, when inflamed, sources of light and heat. Their capacity of producing light and heat is, however, in time exhausted, and when we examine what remains we find them greatly changed; they appear to be different substances, and are no longer combustible.

All bodies that are not combustible are ready to receive caloric, and part with it again, giving out the same quantity, neither more nor less. If a red-hot stone is thrown into a quantity of water, the heat seems to be extinguished or annihilated, but this heat is not lost. I do not positively assert that caloric is never destroyed, or, more properly, changed in its nature; I only say it is a fallacious way of judging of the loss of heat by our senses. It is very clear, that when bodies receive caloric in the usual manner, they retain or part with it in a sensible manner, except in the case of combination, or latent caloric. We may cause a body not inflammable to retain heat longer by surrounding it with bodies of a looser texture; but whatever pains we take the body will cool in time, and the caloric will communicate itself to the surrounding matter: but such is the nature of combustible bodies, that, when heated to a certain degree in the air, they not only become hot, but by proper management they may be heated to any degree, and the heat which is thus generated may be communicated to other bodies without any loss of heat to the combustible bodies: they are in general also luminous; hence their uses in chemistry and the arts. While the stream of heat and light flows from them, they are consumed or changed into a different matter, which cools or heats in the usual manner, and is no longer combustible.

Some combustible substances have been

thought exceptions to this, as spirit of wine highly rectified. To a rude observer it seems to be totally consumed during its inflammation, and he is apt to conclude that the spirit of wine is not converted into a matter no longer combustible*. The reason of the phænomenon is, that when we set the spirit of wine on fire, the flame continues clear without smoke till the last drop of the fluid is consumed, and nothing remains in the vessel. But here is a deception, for a great quantity of matter escapes from the spirit that evades the cognizance of our senses. This may be proved by placing a hollow vessel over the flame, which confining and cooling it, the internal surface of the vessel will be bedewed with a watery moisture. Some have imagined it to be one-third of the spirit, others one-half, and others three-fourths: the fact is, however, that highly rectified spirit affords rather more than its own weight of water by combustion.

The reason we do not see the watery part evaporate is, that the fluid is converted into vapour in so gradual a manner, that it is impossible to discover it by our senses, unless we use those means of collecting and condensing it. Sulphur is another substance which former chemists imagined was consumed or destroyed wholly by fire; but by an easy experiment we find that a quantity of acid is thrown off during the combustion, which is equal in weight to the substance which produced it.

---

* This was even Boerhaave's opinion.

The theory of combustion is now indeed as well understood as most facts in chemistry. According to the second canon I have laid down, combustible bodies are such as will readily combine with oxygen gas; consequently, when any such body is raised to a certain temperature, it begins to be decomposed, and to combine with the oxygen of the atmosphere, and this oxygen during its combination lets go the caloric with which in the state of air or gas it was combined. Hence combustion consists of two things, a decomposition, and a combination; and the substance which has undergone combustion is essentially altered; it is, in fact, a compound of the body which has been subjected to combustion and oxygen. It is of course incombustible, because its base being already saturated with oxygen, cannot combine with any more.

Upon the same principles, if by any process the oxygen is taken away, the substance will again be rendered combustible. To illustrate this whole theory, take a familiar instance. Sulphur, we have just seen, is reduced to a corrosive acid by burning in the open air; but by charcoal applied in a particular manner with the assistance of fire, this acid may be again converted into inflammable sulphur. It is the same thing whether we use charcoal made of blood, flesh, or bone, or whether the charcoal from any vegetable matter. Nor is it necessary to have recourse to charcoal, as pit-coal and other combustible bodies have the same effect. The fact is easily explained upon the principles just laid down. The sulphur, when burned, extracts the oxygen, or acidifying principle, from the air, and is converted into sulphuric acid*. The charcoal when applied again to this acid draws off the oxygen, with which it unites, and forms carbonic acid gas, and leaves the sulphur in its former state.

---

* Formerly called vitriolic acid.

LECTURE XXVII.

CHEMISTRY.

MIXTURE, AND ITS EFFECTS.

The following principles may be laid down with respect to mixture.

1. We find that some bodies cannot be made to unite with others, as oil and water, and water and quicksilver: however shaken together, they will still separate again.

2. We find others unite in the most intimate manner, and form a compound in appearance perfectly homogeneous. Of these some unite slowly and gently, as salt and water.

3. There are other cases, where the union is attended with perturbation and commotion, the production of heat, smoke, and sometimes flame. If I pour into a flask a quantity of water quite cold, and I add an equal quantity of sulphuric acid, which has a great tendency to mix with water, and is likewise cold, the liquid becomes hot, so as actually to boil, emit steam, &c.

Again—If I drop a little carbonate of ammonia, which is a volatile salt, (in a fluid state,) into sulphuric acid, (this experiment requires caution,) the agitation is greater than if a red-hot iron had been dropped into it. This intestine commotion is called *effervescence.*

I shall now exhibit some instances of the mixture of solids with fluids. In their union the solid body is often divided into atoms so minute, that they make with the fluids a homogeneous liquor, and will remain dissolved as long as the quality or quantity of the fluid is not altered.

Thus—Camphor thrown into spirit of wine sinks at first; but, dissolving and uniting by degrees, the fluid remains transparent as before.

Again—Drop a piece of marble into muriatic acid, and bubbles will arise, a violent effervescence is produced, the marble is dissolved into atoms so perfectly minute, that they become invisible, and are equally mixed with the fluid and diffused in it. This is an instance of effervescence between a solid and a fluid; the operation is called *solution,* and the fluid a *solvent* or *menstruum.* In solution a solid must not only be so mixed with the fluid, as to be equally dispersed and never to subside, but the mixture must be perfectly *transparent.* In some mixtures, though the matter is entirely mixed, yet for want of transparency it is not called solution, but diffusion (and in pharmacy *an emulsion*).

Saturation, I formerly observed, is used to signify that some bodies are capable of being united only in a certain proportion, and when a menstruum or fluid has taken up exactly as much of any matter as it is capable of holding in solution, it is said to be saturated. Saturation is sometimes single, sometimes double: camphor in spirit of wine is an instance of the first; volatile salts and the sulphuric acid are an instance of the second, for both may be saturated; the salts by having a proportion of the acid lose their pungency, and the acid its sourness. If more than this portion is added of either, the overplus retains its separate qualities.

Chemists have a power of separating, by the application of heat, such bodies as differ in volatility, and are not too strongly united; but in some instances of solution we find it very difficult. If we endeavour to separate them by heat, we find them capable of enduring a great deal more than any of the bodies, when separate, could have done; and if we apply a still greater heat, the vapour rises without any separation of parts, the volatile carrying the fixed along with them. A mixture of the sulphuric acid and water is an instance: the water in its separate state would be converted into vapour at 212, the acid at 600; but mixed, the water will not evaporate at 212; the heat must be greatly increased, and then the vapour of the water rises mixed with the acid. The alkaline salt known by the name of ammonia is very volatile, but when mixed with sulphuric acid, its volatility will be depressed by the acid, so that it has not the least smell; and if heat is applied, the alkali cannot be raised without a quantity of acid along with it. When marble has been mixed with the *muriatic acid*, the latter loses its volatility, and becomes capable of enduring a violent heat: if heat is applied, the watery particles rise in vapour, and leave the marble and acid so united that no heat can separate them. In this case, therefore, it is impossible by heat alone to separate the marble from the acid, but by the addition of a third body. In doing this, the third body always joins itself to one of the other two; this is called *elective attraction*, or *affinity*.

To give a clear notion of this, by separating the mixtures we just now made, I shall first separate the water and sulphuric acid by the addition of another saline liquor; this liquor acts with great violence on the mixture: the mixture grows muddy as soon as a third fluid is added, and as it cools the salt is deposited at the bottom.

2. In separating the ammonia from the sulphuric acid, the mixture is at present destitute of smell; but on adding a little carbonate of potass, destitute likewise of smell, we may perceive that the ammonia is separated by the pungent smell.

3. So spirit of wine is separated from camphor by mixing water with the spirit.

In this attraction there is a sort of gradation. Thus silver dissolved in nitric acid may be separated by quicksilver, which takes its place. If we add copper, the mercury will be separated.

If we throw in lead, the copper will be deposited —the lead by iron, &c.

Another remarkable phænomenon is, that some bodies are less in bulk, others greater, when mixed. Silver is lighter than quicksilver; yet quicksilver and silver united form a compound heavier than quicksilver of equal bulk.

Water is not increased in bulk by the addition of a small quantity of salt; if the quantity of salt is, however, increased, the liquor will be increased, but not in the proportion of the aggregate weight of the two.

M. Reaumur made the following experiment: a vessel was half filled with water, spirit of wine was then gently poured into it, till the mixture rose half way to the neck of the vessel. The bottle was then shaken, and a little heat was produced; the liquor consequently rose; but when the heat was gone off, the mixture took up less room than it did before the two fluids were united by shaking.

I shall now consider the several theories and explications of the effects of mixture. From the first æra of chemistry, till the time of Lord Verulam, we had no intelligible theory; they seldom went further than to explain one term by another. Thus finding that the alkalies effervesced with acids, whenever they found a substance that effervesced with an acid, the philosophers of the day defined it to be of an alkaline nature.

Most of the chemical phænomena are difficult to explain, because we can scarcely find any thing else with which they can be compared. If a mechanic removes a prodigious rock by the force of one man, it will be cause of wonder to one unacquainted with the mechanical principles; but on examining the instruments by which this effect is wrought, we shall find that the whole depends upon certain fixed laws of mechanism and motion. If the chemist removes a rock of the same magnitude by a small quantity of *nitre*, *sulphur*, and *charcoal*, we shall not so easily understand the manner in which the effect is produced. It is more easy to increase the number of facts than to explain them.

After Lord Bacon, chemistry became more known, and attempts were made for a more rational and popular theory. As mechanical powers are easily understood, we are apt to suppose that the action of bodies depends upon mechanical principles.

The most popular opinions were, that the powers of bodies depended upon their particles having particular figures and motions. Boyle was one of the first who published this opinion, but he did it in a moderate and diffident manner. Many after him, however, have extended this application so far as to show the full absurdity of it, especially the older French chemists. If we were to consult them upon the first experiment we made, they would tell us that the sulphuric acid (or, as they would call it, the oil of vitriol) consists of heavy inert particles, which contain a quantity of fire, and that upon application of the water the particles are dissolved, and the particles of fire break loose and become active; but these reasoners would be puzzled to explain the phænomenon of the same sulphuric acid, or oil of vitriol, with ice. In explaining the dissolution of marble, they say, the acid contains innumerable wedges or needles, which get into the pores of the marble, and throw off its particles, which are suspended in the fluid like a boat by its oars*. But supposing the particles sharp and pointed, they would require a force to make them act. In answer to this, they tell you that the particles of fluids are agitated in a constant and irregular manner; they refer you to the beams of the sun let into a chamber, in which you will see the particles of dust moving in all directions. It is true, there is a motion of this kind in the air, which is the most elastic and tremulous of all fluids, every motion throwing it into agitation; but this is not so rapid as to throw the particles against each other with sufficient force to produce the effects in question. There are many instances of solid bodies acting with violence upon one another, as corrosive muriate of mercury, when powdered, and mixed with pure antimony in powder. There are many facts also relating to fluids, which render this theory very unsatisfactory. Nitric acid, for example, dissolves silver, and not gold; aqua regia, or nitro-muriatic acid, gold, and not silver; the gold is the denser of the two.

---

* This is the very expression of Lemery.

In the dissolution of solid bodies in fluids, they tell you, the reason why a solid body continues equally suspended without subsiding from the fluid, is, that the division of the bodies is so minute, that the weight of the particles is not sufficient to overcome the resistance of the fluid. This, however, does not explain the dissolution nor the dispersion of the solid particles through the fluids.

The last theory I shall mention is that of Sir Isaac Newton, which is now generally received, and for which I refer to the thirty-first query at the end of his Optics.

Sir Isaac Newton supposes that the phænomena of chemical solution arise from a disposition in the particles of one body to unite with the particles of another. Thus, when two bodies on being mixed unite with effervescence, &c. the cause of this phænomenon he supposes to be a powerful attraction between them, which disposes them to unite very strongly with a rapid and accelerated motion; whence the visible effects in the attraction which obtains between the particles of the fluid and solid; this attraction is more powerful than that which binds the particles of the solid together. In consequence of this attraction, the mixture is much more difficult to evaporate than either the solid or fluid in their separate state. Heat produces vapour by lessening the attraction between the particles of a body; it enlarges the dimensions of a solid till it becomes fluid; if continued, it enlarges the dimensions of a fluid to vapour. According to Sir Isaac Newton, this attraction is equal at equal distances, and at unequal distances unequal.

When the volatility of a body is repressed by mixture, and the two cannot be separated by heat, the separation is produced by the addition of a third body, which has a stronger attraction for one of the two bodies than they have for one another. This kind of attraction, from the circumstance of certain bodies uniting with a kind of preference to certain other bodies, was at first named elective attraction; and afterwards, for a similar reason, *affinity*, which is the term at present in most general use.

Many of the hardest bodies are very quickly separated by mixture. Metals require a very great force to divide them mechanically, but this division is easily effected by chemical solvents. But the following observations will serve more fully to explain the nature of *elective attraction* or *affinity*.

1. This sort of attraction differs from that of gravitation, electricity, and magnetism, in not obtaining between large and sensible parts of

matter, but only between its minute and invisible particles. Thus, if we place a piece of salt as near as possible to water, it will not unite with it, unless it is in contact.

2. The minuteness of the particles into which bodies are divided by mixture is beyond the power of imagination. We may form some sort of notion of this minuteness, by dissolving a small grain of the size of a pin's head of nitrat of silver in a quart of river water. The water is tinged with a milky colour; every particle of water has therefore a sensible quantity of silver in it. If to this mixture we add the solution of muriate of soda, or common sea salt (a transparent fluid), we shall see the little grain of silver, which was dispersed through the whole of the water, separating in a subtile powder, and falling to the bottom. The saline liquor added has no disposition to disturb the transparency of the water, when it contains none of the silver; yet it is no sooner added to this solution of silver than the whole of the liquor becomes muddy, and every drop appears to have contained particles of the metal. The nitrat of silver is a combination of the nitric acid and silver. The particles of silver were actually divided from each other by the nitric acid before put into water. That the whiteness is occasioned by the common salt, of which there is a little in most river water, is plain by adding some of it to pure distilled water, which produces no whiteness at all.

3. The influence or energy of this attraction reaches to a distance so small, as to be imperceptible to our senses, as it does not appear to act till the bodies are in contact. Of this there is an instance in the difficulty of applying the particles of sulphur and mercury sufficiently near to make them unite. In this respect chemical attraction is analogous to the attraction of cohesion. For if two pieces of lead are pressed strongly together with a twisting motion, so as to bring them into violent contact, they take hold of one another almost as firmly as if united by fusion.

From these observations we shall understand some of the principal laws of mixture and solution.

I. When we desire to make two bodies act upon one another, it is necessary that one or both of them should be fluid, or rendered fluid, or disposed to fluidity, immediately after mixing. This rule is applied to salts in particular, "which do not act unless in solution." To illustrate this by experiment:

First. To crude muriate of ammonia in powder (which is a compound of ammonia or volatile alkali and muriatic acid, which has a strong attraction for it, and depresses its volatility) I add another salt in powder, which has a greater attraction for the fixed salt than the alkali; but though I take great pains to mix them, they will not act; but when dissolved they immediately act on one another.

Second. Salt of amber mixed with potass while kept dry will continue separate, and the brown and white particles may be distinguished by a microscope; but if water is thrown on them they immediately act upon each other.

The reason why fluids promote their action upon one another seems to be, I. That they bring their particles into closer contact than it was possible to bring them by any other means. The surfaces of solids are rough, and there seems to be an atmosphere over them which prevents them from uniting. Sir Isaac Newton calls it a tenacious atmosphere, and extremely subtile, upon which depends a variety of electrical facts. When a solid is applied to another solid, the particles of each are united by the attraction of cohesion; therefore they will not act upon each other, but they will act readily when this attraction of cohesion is removed by solution. But whatever the cause, the law is founded in experience. The necessary fluidity is obtained by dissolving the body in a fluid that produces no change in its qualities: thus, salt is dissolved in water; or by melting it, as metals; or by converting it into vapour, as in bodies which assume the form of vapour before they become fluid. The terms for these operations are *solution*, *fusion*, and *evaporation*.

II. When we would dissolve a solid in a fluid, divide the solid mechanically, or by other means increase its surface. If a brittle body, by pulverizing; if a metallic, by beating it into leaves. The reason is plain, viz. that the fluid only acts on the surface with which it is in contact.

III. The action of one body on another is promoted by moderate heat, which performs the solution sooner in the action of a fluid on a solid; for, on removing the heat, the additional quantity which the heat had enabled it to dissolve will be deposited. This is particularly the case in salts and water. In general, the action of bodies on each other is more languid as the heat is less, and the contrary. From these facts it appears that the attraction the particles of one body have for those of another is increased by heat; and, on the contrary, the attraction between the particles of the same body is diminished by heat, as is evident in the formation of vapour.

Digestion is the continued application of heat to the bodies that are to act on each other, and may be performed in an ordinary vessel when the bodies are not volatile; when they are, a reflecting vessel is used to condense the vapour which is returned back to the first vessel: this is called *circulation*. In this process the condensing vessel is placed above. *Cohobation* is an absurd term; it, however, means the collecting of the vapour into the second vessel, and pouring it back into the first as in circulation; but instead of placing the condensing vessel over the first, it is placed on one side.

By a knowledge of chemical attraction a chemist obtains the means of separating compound bodies, viz. by applying a third substance, in order to decompound them by means of the superior elective attraction which one of the bodies may have for that third substance. Hence it appears that Sir Isaac Newton's theory is extremely probable, yet it is not altogether sufficient; for why may not the three substances unite? This may perhaps arise from a repulsion between the third substance and one of the other two. But I am not inclined to multiply causes.

Geoffroy was the first who formed tables of the elective attractions of bodies, which were greatly extended and essentially corrected by Bergman.

The perfection of chemical science consists in what is called chemical analysis, that is, the resolving of bodies into their constituent parts; and it is surprising to reflect how far these operations have been carried by modern chemists. The food we eat; the medicines we apply as remedies for diseases, have all been, if I may repeat the figure employed in the first of these chemical lectures, anatomized and dissected.—Hence we are the better enabled to judge of the salutary nature of each. All the productions of art and nature have, in short, been investigated, and their composition fully explained.—This is the true practical, I might say the really philosophical use, of chemistry; and to this every student ought, in the first instance, and as the first object, to apply.

The analysis of bodies is effected, as was formerly stated, partly by the agency of heat, still more, perhaps, by that of mixture, and still more by the united effects of both, judiciously applied. It is of the utmost importance, therefore, that the student should render himself master of the affinities of different substances, and know with what bodies they will unite in solution, &c., and what bodies they will dislodge. The acids are the most powerful agents as menstrua, or in the liquid state, and with their affinities for the different solid matters it is necessary to be well acquainted; for by their means alone many of the most important facts in natural philosophy may be investigated and explained. But in a state of fusion, which may commonly be effected by the means of heat, most bodies may be brought to act upon each other.

In the subsequent lectures the action of the acids will be pointed out, also different modes of analysis, under the heads of Earths, Metals, and Mineral Waters. But in so very short a sketch of the doctrines of chemistry as these few lectures can comprise, it is not possible to go far into the detail; and the most effectual processes can only be found in the larger works on this science, particularly those of Bergman, Kirwan, and above all, that admirable compendium of modern science Dr. Thomson's System of Chemistry.

LECTURE XXVIII.

CHEMISTRY.

CHEMICAL APPARATUS.

THE instruments used in chemistry may be divided into three branches: 1st, The vessels that hold the subjects on which the effect is to be produced: 2d, The apparatus for producing heat: 3d, The means of regulating or applying heat in the best manner.

Was it in our power, we should wish that the vessels used in chemistry should possess the following properties: 1st, Transparency: 2d, The property of resisting the action of corroding substances: as also, 3d, Sudden changes of heat and cold: 4th, Strength, in order to confine elastic vapour, &c.: 5th, The power of enduring heat without melting. But no matter in nature is possessed of all these properties. The common materials are glass, metals, and earthen ware.

1. The greatest inconveniency of glass vessels is, that they do not well endure sudden changes of heat and cold. It is the rule to make glasses which are to bear heat as *thin* as possible, provided they are strong enough to be handled,

The effect of making them thin is, that their surfaces are more uniformly heated, that is, one surface is not heated before the other, and consequently they bear that disproportion of their form which heat occasions. They are more flexible too; and a spherical form contributes to this effect. White glass best resists sudden changes of temperature, and common green glass the higher degrees of heat in the sand furnace. One circumstance in particular to be regarded is the *annealing of the glass*. This is done by putting the vessels, while red-hot, into a furnace of nearly the same temperature, and letting them cool gradually, for if hastily cooled they are remarkably brittle. This phænomenon is hard to be accounted for; but we have a strong instance of it in what are called glass tears, or Prince Rupert's drops, which is melted glass dropped into cold water. The greatest number of these drops falling into atoms, those that remain are in the form of a pear, with a tail not thicker than a thread. If we break a little bit of the tail, the whole flies into powder with great explosion, and they sometimes fly without any thing that we can perceive disturbing them. A certain thickness of the glass is crusted over, if this crust is penetrated the whole flies asunder; yet when the thick end is ground till a certain point is worn off, the explosion does not take place; this is a fact that cannot be explained till we understand better the nature of cohesion.

It is, however, somewhat analogous to the sudden crystallization of salts by agitation. The contraction necessary for developing the matter of heat is prevented in the first instance by the sudden formation of a solid crust. On the latter being split in several parts at once, the instantaneous mutual contact of the internal parts, and consequent liberation of the *latent* heat, perhaps, causes an explosion.

2. Metal vessels want transparency, yet their use is indispensable. Iron serves for sandheats, distilling pots, and other purposes requiring strength and durability; copper, for the more bulky utensils employed in boiling and distilling. Condensing worms and dyers' kettles are made of tin a little hardened by copper; lead, hammered out from a thick plate, makes good boilers for such acid and saline liquors as would corrode iron. It is also much used for lining wooden backs to perform crystallization in the great way.

But the experimental chemist requires crucibles and evaporating vessels of pure silver and platinum; the former for the caustic alkalies, which have no sensible action on silver, though they attack almost every thing but that and gold. Platinum makes almost an universal implement, resisting the greatest heat of a charcoal fire, and the action of all the simple acids, but not of nitromuriatic acid and the alkalies. Crucibles of these metals, being fitted with an alembic head of glass, serve for most distillations by the heat of the lamp.

3. Earthen vessels of the best kind resist the strongest heat without melting, and are not easily corroded. Vessels made of *clay alone* are very close and compact, but are liable to break from their inflexibility, as well as to melt. To remedy these, *sand* is added, which endures the most violent heat without melting, and at the same time lessens the expansion of the clay, and consequently renders it less apt to break. If the vessel is required to be very compact, more clay and less sand must be used: they must be heated and cooled slowly. If vessels are necessary that will bear to be heated sooner, more sand must be employed. Mr. Pott, of Berlin, recommends powder of clay, burnt till it is quite hard, instead of sand, which has all the advantages without the inconveniences of that material. Chemists have long wished to discover a vessel in which lead may be vitrified without loss. This metal dissolves common vessels, as water dissolves salt. Mr. Pott's method answers this purpose extremely well. Dr. Lewis recommends a porcelain of bottle glass baked in sand*. Black lead vessels endure heat best.

The forms of the vessels vary according to their uses.

I. Vessels for Fusion. The most common

---

* See his Commerce of Arts.

for this purpose are crucibles of a conical form; they should have covers to keep out the fuel and air. Lead is commonly fused in iron, and salts in glass.

II. VESSELS for EVAPORATION; these may be divided into three classes:—1. for *Evaporation*; 2. *Distillation*, or *Sublimation*; 3. *Cementation*.

1. EVAPORATION. Flat vessels may be used when the heat is gentle, but in a strong heat crucibles must be employed. See Pl. V. fig. 11 and 12.

2. DISTILLATION. Distillation is of three kinds:—1. Distillation *per descensum*; 2. *per ascensum*; 3. *per latus*.

The first is when the heat is applied above, and the vapour falls directly downward into a condensing vessel. In this manner oil of cloves used to be distilled, but it is now laid aside. The tar manufacture is, however, still carried on by this mode. The wood that produces the tar is put into an oven, which is heated from above, and this causes the oily and resinous parts to sweat out and fall into water, which is placed below to receive it. Zinc is also prepared in this way from *lapis calaminaris*, one of its ores.

2. By the common still *per ascensum*. For corrosive substances we use CUCURBITS, or glass vessels in the shape of an egg, which are called by some practical chemists matrasses or bodies. See fig. 13. The common still used for the distillation of spirits is represented in fig. 14.

It consists of a boiler covered by a metal head, A, usually of copper, for collecting the vapour, which is made to pass through a spiral tube called a worm, immersed in a tub of cold water, B, for the purpose of condensing the spirit, which comes out at the pipe C in a fluid form.

3. By the *retort* and *receiver* (see fig. 15.) we perform the *lateral* distillation. Those that have the neck of the retort descending into the lower parts of the receiver, are more useful than those in which the neck of the receiver is inserted in the retort. Some have contrived them with an opening in the back for the mixture of bodies that emit elastic steam: this hole is stopped during the process, but not very tight, so that if the vapour is very elastic it may find its way, and the vessel be preserved. The conical receiver is accounted best. It is dangerous to restrain the steam too tight, and therefore in luting the retort and receiver do not screw them too tight. When a degree of heat capable of softening glass is required, the retort may be coated over with clay and sand, which do not contract with heat: for very intense heat, we must have a retort of the same materials with the crucibles. In many operations of the retort we have occasion to mix two substances, in order to obtain a third or new product, which is to rise in vapour upon mixture. In this operation the neck of the retort must be kept very clean and dry. In sublimation, when the vapour condenses into a so-

lid, we use a cucurbit with a blind head, or without a pipe, but more commonly a retort and receiver: the retort must have a short and wide neck. A *capital* is sometimes necessary to receive the vapours that condense in a fluid, before those that condense in a solid begin to rise. Many sublimates are difficult to be converted into vapour, and, when converted into vapour, soon condense; for these a Florentine or common oil flask answers sufficiently well.

The *alembic* (fig. 16.) is used for distillation when the products are very volatile. It consists of a body, A, to which is adapted a head, B. The head is of a figure inclined to conical, and has its circumference or base depressed lower than its neck, so that the vapours which rise, and are condensed against its sides, run down, and are conveyed by the nose or beak, C, into the receiver, D. The principal object of this instrument is, that in distillation, and more particularly sublimation, the head may receive the more dense and dry products, while the more volatile pass into the receiver.

An *aludel* is analogous to adopters in distillation: its use is to condense bodies according to different degrees of volatility. What remains after the spirit or sublimate is taken off, is called the *residuum* or *caput mortuum*.

The 3d process is CEMENTATION, when vapours act upon one another, by laying the materials in alternate layers *stratum super stratum*, It is thus copper is converted into brass, viz. by alternate layers of copper and lapis calaminaris mixed with other substances: the vapours from this last tinge the copper yellow. The vessels for this process are chiefly crucibles.

III. **Vessels for Solution.** Those of a conical form are often very convenient, as they bear sudden alterations of heat, and prevent the easy escape of vapour. To this class may be referred the *pelican*, and *Papin's digester*.

Solution is often partial, in which case it is necessary to purify it by *filtration*. The common means are through a spongy kind of paper, such as the common blotting-paper, and to separate powdery matter from fluids, *chalk-stone*.

Among chemical instruments may be reckoned the *iron rod*, or knife for *cutting glass*. By applying this iron red-hot we may lead a crack in a glass in any direction, moving the iron a little before the crack, which follows the iron. If there is not a crack in the vessel, the iron must be applied red-hot to the part we want to separate, till the glass is well heated, and then apply a file dipped in cold water to the part, and it will immediately crack.

The means of producing heat are seven, viz. 1. Animal Heat; 2. Friction or Percussion; 3. Electricity; 4. Mixture of Bodies; 5. Fermentation; 6. Rays of the Sun; 7. Fuel.

I. *Animal Heat* is only used in the regulation of the thermometer, by putting it in the mouth.

II. *Friction* or *Percussion* is applied to some purposes in common life, as in fire-arms, where fire is produced by the percussion of the flint against the steel.

III. The *Flash* of *electricity* has not been much attended to by chemists, though its effects on metals are great, as you have seen in the lecture on electricity. Professor Davy has, however, latterly applied the kindred science Galvanism with great success in chemical investigation.

IV. *Mixture.* This heat, like the former, is too transient to be applied to any useful purposes. We may, however, account mixture as one of the means of lessening heat occasionally, and producing cold. To obtain low degrees of heat, we have recourse to a mixture of water or pounded ice with salts; of these muriat of lime with snow is most powerful. Snow or ice mixed with strong nitrous acid produces also a great degree of cold, even such as to freeze the mercury in the bulb of the thermometer; yet we have reason to believe that the cold is limited. To retard the entrance of heat, the mixture ought to be wrapped in wool: the cold remains at its greatest degree while any of the ice or snow remains unmelted.

V. I may mention the heat produced in *Fermentation*, though this mode of applying heat is chiefly employed in promoting vegetation, and in Egypt in hatching eggs. In chemistry it is used where a long and gentle heat is to be applied, and was much in repute with the old chemists. Horse dung, and tanner's bark after it has been used, have a degree of heat equal to 120 degrees or more. The horse dung rises soonest to this degree, but it flies off in about a month; the bark retains it for some months. It is necessary that there should be a proper quantity of moisture, and that it should also be in a compact heap; otherwise it has too much surface for its bulk, and the heat is dissipated.

VI. The *Rays of the Sun.* When a subject is exposed to them, a degree of heat sometimes higher than that by fermentation is produced, but it is not so constant. It is often used for the promotion of the action of fluids upon solids, and is then called *Insolation.* It is used for the dissipation of moisture; and thus vegetables are sometimes dried. It has been erroneously thought that it was better to dry them in the shade; but by experience it is found that they are always better cured by a quick heat than when dried slowly. The sun has a remarkable power in discharging colours, and a particular effect on some saline bodies. The force of the sun's rays is greatly increased by condensing them, as by lenses, speculums, or burning-glasses. Concave mirrors and refracting lenses have been used to melt metals and stones that were formerly thought fixed. The speculum made by Viletti at Lyons was three feet in diameter; its focus half an inch. The principal point in the improvement of lenses is to form the focus at as small a distance as possible; but this requires so great a convexity, that by the thickness of the glass a great part of the light is turned out of its course. Another kind of burning mirror is made of pasteboard, with gold leaf burnished on it. Buffon had one of this kind, and he describes its effects as astonishingly great.

VII. *Fuel*, which is the most successful means of procuring heat, for it affords it either gentle or intense. Its varieties may be reduced to the following heads:—

1. Fluid combustibles are the most equable and manageable sources of heat; they burn by a wick, as spirit of wine, oil, &c. But spirit of wine is the best, since its vapour is free from soot, and we may increase or diminish the heat by the number of wicks: the cotton is not consumed in the least, as the heat sufficient to convert the spirit of wine into flame is not capable of scorching vegetable substances: spirit of wine (when highly rectified) leaves no excrementitious matter. The flame of oils emits soot, but this is somewhat remedied by having small wicks, and increasing their number, or still better by the lamps with glass chimneys of Argand's invention, which have great power. Oils scorch the wick and change its texture, so that it does not suck up the whole of the oil: incombustible flax, or asbestos, &c. have been used, and answer the purpose better than cotton. Oils also of themselves leave a fixed carbonaceous matter which clogs the wick. Some oils,

however, are more completely inflammable than others, as spermaceti is better than train oil.

2. *Peat* or *Turf* produces a gentle heat; when crude the smoke diminishes the heat, and spoils the vessels; when it has been red-hot the smoke is expelled, and a kind of charcoal remains.

3. *Charcoal* of *wood*. This is the chief fuel of chemists abroad: it kindles quickly, has few vapours, produces few ashes, and they have scarcely any disposition to melt so as to clog the vessels. If the ashes do melt, it is only in the smallest quantity. It is capable also of producing the intensest heat; it is, however, soon consumed, and must be quickly renewed. Though the charcoal seems free from fumes, yet there is an evaporation of humidity till it becomes red-hot *.

4. *Fossil coal charred* has much the same qualities of emitting no gross smoke, &c. The reason these fuels improve by being charred is, that before they are so they contain a vast quantity of moisture, which is dissipated in steam or smoke; these, not being capable of a greater heat than 212, are apt to cool the substances, and sometimes to break the vessels.

5. *Wood* or *Coal* in their crude state are inconvenient, on account of the smoke or vapour they emit. The smoke, in fact, that rises from all

---

* The smoke from common fuel is as dangerous as the fumes of charcoal; but as it is distinguished by being disagreeable we avoid it before it produces any ill effects.

bodies in flame is a vapour not inflamed. Bodies that do not flame may heat particular substances more than those that do; yet flaming substances are employed in glass-houses and other works where the greatest heat is wanted. To produce this excessive heat a great quantity of air is necessary: it is necessary too that the air should be thoroughly mixed and agitated with the flame; the sooty matter will not otherwise be consumed. The flame of a candle will not produce a violent heat, because the air is not sufficiently mixed with it: in a smith's forge, on the contrary, the air is blended with the flame. In heating a furnace, it is of great consequence to throw in but little fuel at once; for if much is thrown in, a great part of the vapour rises in a thick smoke; but if the furnace is gradually supplied, almost the whole vapour will be inflamed. Hence it will be manifest, that flaming bodies are not proper when a moderate and equable heat is required.

The object of FURNACES is to confine the heat as much as possible; the air furnace consists of

1. An ash-pit open.
2. A chamber for the fire upon a grate.
3. A door for fuel.
4. A vent for smoke.

In a furnace thus constructed, the air over the fuel being rarefied rises through the vent, and is succeeded by fresh air rising through the grate, and penetrating through the burning fuel. On this the rising of the smoke in a common chimney depends; and on this principle may be explained Agricola's observation on the constant circulation of air in mines. When miners open a vein, they begin at the foot of the mountain, as it is generally the richest, and make what they call a level or drift in the side of it, inclining a little upwards, for the convenience of drawing off the water. After they have bored a little way, they begin to want air, and their lights go out. To remedy this they sink a perpendicular, which they call a *shaft*, till it meets with the level or drift. As soon as this communication is made, there is a constant current of air pressing in at the drift and out at the shaft in winter, and a contrary draught in summer. The reason of this difference is, that as the heat in summer, and cold in winter, do not penetrate deep beneath the surface, the internal parts of the earth are generally of an equal temperature between the heat of summer and the cold of winter; so that in winter the air getting in at the drift is warmed by the air in the bowels of the earth, and ascends by the shaft. Again in summer, the air in the bowels of the mountain being colder than the external column of air in the shaft, becomes condensed, and flows out at the drift, its place being supplied by the air flowing in at the shaft. But when the external and internal air are nearly of the same temperature, as it is sometimes in spring and autumn, the circulation is greatly impeded; a circumstance dangerous to the workmen, and which they obviate by making large fires in the mines.

It may not be quite improper, perhaps, in this place to notice the ventilation of air in chimneys, which are liable to two faults: first, the want of a draught up the chimney; the second, the wind being driven down, and the smoke along with it, into the room. The first must arise from some obstruction, as too much soot, or from the too great closeness of the room; for in modern rooms the finishings are so close, that there is often not a succession of air to supply the place of that which rises up the chimney, therefore the smoke rises a little way, and returns again into the room. Lessening the vent is often a remedy, or opening a pane of glass. In new houses, where the chimneys are generally cold, the air is often condensed before it reaches the top, and consequently falls back again. Old-fashioned houses often have their vents too wide, and was it not for the openings in the room there would not be a circulation. The second defect is gusts of wind being now and then driven down, though in general the smoke may rise well enough. This does not depend on the construction of the room or the chimney; it arises from another cause. As the air passes over the house, it must, especially in streets, be necessarily thrown into eddies and irregular waves, as water in a river, from the stones, &c. Hence the wind often strikes down the chimney, which then must be raised above the level of the buildings that occasioned the eddy; or a machine may be placed at top to turn with the wind.

To return from this digression. The heat in furnaces is regulated by diminishing the aperture above, or that below. This method of managing a fire is called *damping*, and is best done by varying the aperture below. In fig. 17. is represented the common small furnace for melting; A is the ash-pit where the air enters, C is the fire-place, containing a covered crucible stand on a support of baked earth which rests on the grate, D is the passage into E, the chimney. At D is a cupel placed in the current of the flame, and at F is an earthen or stone cover, to be occasionally removed for supplying the furnace with fuel.

The heat of the *air furnace* is in general in proportion to the height of the vent; but when the quantity of fuel is such that the vent cannot be carried to a sufficient height, i. e. when the chamber is extremely large, then other artificial means of throwing in a blast of air are necessary. Bellows are made use of for this purpose. The improvement in the Carron works, by throwing in the air through a cylinder, is very considerable.

In blast furnaces the pipe of the bellows should be a great deal larger than is common, that the whole air may be thrown into the fire-place at once. The eolipile, which is a hollow ball of metal, filled with water, with a long pipe, and which being heated sends forth a volume of steam, has also been used for sending a stream of air into the furnace. Some have proposed putting it into the ash-pit for this purpose, and Dr. Lewis made the experiment, thinking that the steam might more easily enter the fire, but it did not answer; for, in fact, it is not the steam that increases the inflammability of the fuel, but the air which it impels before it. Steam itself extinguishes flame, for a candle put into the steam of boiling water is effectually extinguished.

It was before observed, that flame, when mixed with air and agitated, produces the most intense heat. The reason why the agitation of flame increases the heat must be obvious. Flame is ignited vapour, and by being agitated, a greater surface of inflammable vapour is exposed to the contact of the atmospherical air, and in that situation which is favourable to the combination of the oxygen of the air with the inflammable matter, which is therefore condensed, and the caloric it contained is set free. To illustrate this by the *blow-pipe*, which is a tube of glass or metal bent, it will be more convenient if there is a globe blown at the angle of the pipe to condense the moisture of the breath. By this we find a flame of a very moderate size, when agitated with air, produce a very intense heat. This instrument is often useful in adjusting small vessels, or in sealing them up, or in trying a fossil by exposing it on a piece of charcoal to the heat produced by it. There is some art in managing the blow-pipe so as to produce a continued stream of air. This is effected by applying the tongue to the roof of the mouth in such a manner as to interrupt the communication between the mouth and the nostrils. By these means the operator is enabled to breathe through the nostrils without varying the blast through the pipe. A wax candle with a thick wick is very convenient for experiments with the blow-pipe; but a good tallow candle will answer most purposes. The body to be acted upon should seldom exceed a pepper-corn in size.

The *reverberatory furnace* for melting iron, &c. has a square fire-place, and an oblong oven, from the further extremity of which rises a long vent; and the furnace beating down the flame on the metal causes a violent heat. In fig. 18. A is the fire-place, B the dome and chimney, which is moveable, and which incloses C, the vessel containing the metal, which by this contrivance is surrounded by the flame.

The *potter's kiln* has a large cavity of a conical form; the flame rises in the bottom of the cavity, and flies out at the top like a torrent of liquid fire. This will do when a moderate heat is required; for stone ware or porcelain the kiln must be provided with six or eight furnaces for sending up flame.

The *glass-house furnace* must be constructed in such a manner as to allow the workmen to have free access to it without diminishing the heat.

The reason why brick furnaces often crack is, their internal parts being more heated, and consequently more expanded than the external: to prevent this the furnace should be heated and cooled gradually, at least till properly seasoned.

The furnaces employed in heating retorts only differ in a contrivance for heating the vessel slowly and equally over the surface. These probably have got the name of *balnea* from water being mostly used, which is safest when no great heat is required; and this is called *balneum mariæ*. When sand is used, it is called *balneum arenæ*. Some have recommended steel filings, and Dr. Lewis quicksilver; but as quicksilver soon evaporates, I would prefer the softer metals, as bismuth, &c. It is often found useful to make use of air, which is called distilling in *copella vacua*. The vessel is to be placed in the middle of an iron vessel, suspended by iron hooks, and you must close the iron vessel so as to exclude the external air. The lamp furnace has been used both for the purposes of evaporation and digestion.—For various hints on furnaces, see Lewis's Commerce of Arts, and Mr. Nicholson's Dictionary of Chemistry.

Lutes are commonly used for joining two vessels together, and stopping the cavities. The ordinary lutes deserve the name less than others, having no clay in their composition: they are used to stop the junctures of vessels when the heat is gentle; but it is better to leave a hole made with a pin than to shut the juncture quite close. Flour and water with gum arabic is good for distilling; also linseed meal (from which the oil has been expressed) makes a remarkably tight luting. The most convenient linings are bladders cut into slips, and moistened; the inside of the bladder must be applied next the vessel*. When the fumes are corrosive, *fiery lutes* must be used; the best of which is pipe clay mixed with seven times its quantity of white sand. The clay only serves to combine the particles of sand together, for sand resists the most violent heat. A good luting for lining the internal part of a furnace is made of charcoal dust and water with one-fourth of clay, over which spread a covering of sand and clay, and beat them well with a hammer. The charcoal will last two or three years; the clay is mixed with the charcoal to prevent its cracking.

---

* When a bladder is used with the retort and receiver, a hole may be made in it with a pin, by which the operator may judge of the contents by the smell.

Mr. Nicholson* most judiciously remarks that the ingenious student in chemistry, when he has acquainted himself with the first principles, will easily perceive that there are few philosophical inquiries which require a large apparatus of furnaces or vessels. A tobacco pipe (the bore of which ~~must be~~ stopped with good clay) is a very useful crucible, in which many operations may be performed with a good pair of double bellows. An earthen pot, or an iron ladle, will contain a sand bath, and common phials, or Florence flasks, serve very well for matrasses. Chafing-dishes, or small iron stoves, will produce a great heat if well managed; and the blow-pipe and spirit lamp, with a set of small retorts and receivers, may be applied to the performance of almost every part of experimental chemistry.

---

* See his Dictionary of Chemistry.

LECTURE XXIX.

CHEMISTRY.

SALTS.

THE objects of chemistry are commonly divided into *salts*, *earths*, *combustibles*, *metals*, *waters*, and *vegetable* and *animal substances*. By taking them in this order, we shall find that those of a similar nature, and which have most qualities in common, are united together.

Salts are commonly defined to be substances which are fusible, volatile, soluble in water, not inflammable, and sapid when applied to the tongue. These qualities are united to distinguish them from other bodies which will be afterwards mentioned. The first objection that has been made to this definition is, that their fusibility or volatility are not distinguishing characters, as we have reason to conclude there is no species of matter incapable of both: but what is meant here is, that they are easily melted and converted into vapour with a moderate heat. Another objection is, that the absence of inflammability is mentioned as a characteristic; whereas many salts by a vigorous test show signs of inflammability.

Muriat of ammonia, as well as the pure salt of that name, will deflagrate.—But it must be remembered that hydrogen, which is a substance highly combustible, is one of the component parts of ammonia. This then is an imperfection in the definition not easy to be surmounted; but where objects are numerous and diversified, it is difficult to class them.

It is obvious from what was stated in the first lecture on chemistry, (Lect. XXV.) that all salts are compound bodies. The acids all consist of certain bases or radical principles which give the particular character to the salt, and the acidifying principle, or oxygen. Of the three alkalies, the volatile or ammonia is a compound of hydrogen and nitrogen; and soda and potass have been lately discovered to be metallic oxides, as stated in a preceding lecture.

The most simple state of salts is a mass, white, brittle, and in some degree transparent. Salts in certain degrees of heat are fluid, like oil, and transparent; when cooled they return to their former state, and are semi-opake. They differ in their degrees of volatility and fusibility: some fly into vapour with the least heat, others in a violent heat remain nearly fixed; most of them require to be heated hed-hot, yet all may be brought into fusion.

All saline substances dissolve more or less readily in water. The attraction of salts for water is however different in different salts. Those that have the greatest attraction for water require least for their solution: some of them possess so great an attraction for water, as to absorb it from the air. These are called deliquescent.

The first phænomenon in the mixture of salts with water is the separation of air from the water by a seemingly elective attraction. This appears by a muddiness which proceeds through all the parts of the fluid, and is occasioned by a number of little bubbles, which rise to the top so as to form a scum; when all these are risen, the water becomes transparent. This deserves to be taken notice of, as many have been deceived by it, especially those who have written on mineral waters. They often mention effervescence in them, where there was none, and the appearance of it was nothing more than the air escaping.

Another phænomenon is the alteration in the heat of the mixture. In some cases it is colder, in others hotter. When heat has been produced, it has been thought owing to the violent attraction between the salt and water; for the production of cold there has been no theory offered but that of latent heat, as stated in a preceding lecture.

Another phænomenon is, that if we add more and more salt to the water, it will be more and more slowly dissolved, and after a certain quantity it will dissolve no more. When the water will dissolve no more, the point at which the salts cease to dissolve is called, as was before mentioned, the point of *saturation*. The proportion of water is very different with respect to different salts: some require only a quantity of water equal to themselves in weight. A saturated solution dissolves more salt if a little heat is thrown into it. Common salt is the only exception to this general rule; it dissolves with equal ease in the same quantity of cold water as in warm. Mr. Macquer thought the deliquescent salts were also exceptions; but this remark is by no means just. We are not agreed as to what salts are to be called deliquescent, and what not: their deliquescence may depend sometimes on the particular dampness of the air, and sometimes on their own particular condition.

From the phænomena attending the dissolution of salt Sir Isaac Newton thought that there was an equal distribution of it through a determined space of water, and hence the deposition is in a regular order; hence also, if a space of water is increased by expansion, it is capable of arranging a greater number of particles of salt than it otherwise would do. That something of this kind really takes place is evident from experiment, as that part of the water which contains the least salt will have the greatest attraction for it; and thus the distribution of the salt will proceed till the particles are arranged at equal distances through the whole fluid. There is, however, a seeming objection to this, viz. that when the salt is merely thrown into the water, the particles do not rise and disperse themselves immediately, but it is a long time before the salt is dispersed through the whole. This, though a seeming, is not a real objection. It is true, it is a long time before the salt dissolves, but this is in consequence of the very cause on which distribution depends; and in time the salt will be equally distributed through the whole. Throw a heavy salt into a glass of water (sulphat of copper, or blue vitriol, for instance), it at first sinks to the bottom, and after some days begins to impart some of its colour and qualities to the particles of water immediately surrounding it. As the water in contact only acts upon the salt, it is soon saturated, and, being thus made heavier, remains round the salt in the state of an atmosphere. The whole of the attraction of the water, then, can only act on this surrounding atmosphere, as chemical attraction reaches to so small a distance. In a little time another stratum will be formed, containing less salt than the former. Innumerable horizontal strata will at length be formed containing less salt: hence the slow diffusion if not assisted with agitation. The sulphuric acid is used in bleaching, by dilution with the water in which the linen is steeped. The bleachers at first thought it was sufficient merely to throw the acid into the water: by this, however, some of the linen was always corroded; for the sulphuric acid sinks to the bottom, and there remains a long time before it is distributed. When mixed thoroughly by agitation, the salt will never separate again; for the solution of salts is as perfect as any in chemistry.

Salts are separated by evaporation in two ways: 1st, By a *brisk heat* till all the water is dissipated. This is called *evaporation to dryness*, and the salt appears a shapeless, pretty firm mass, but the particles are very small. If this operation is often repeated, it is observed that some of the salt is always lost. 2d, By a gentle heat, and partial evaporation. The salts then shoot into regular masses with polished surfaces, more or less transparent, called crystals, from their resemblance to that stone. Salts deposited in this manner have a tendency to a particular form, though the different manner of conducting this process produces some variety in the figure of the crystals. The crystals are larger and more regular if the liquor is not evaporated too much, and if it is cooled slowly in a vault or cellar. There is a degree of transparency in the concretion; and if the process is repeated ever so often, the salt will have the same form. Each particular species of salt has a distinct form of crystals peculiar to itself. Nitrat of potass (common nitre) appears in the form of oblong pillars with six sides: muriat of soda (common salt), in a cubical form: nitrat of soda (cubic nitre), in a rhomboidal: sulphat of soda (Glauber's salt), in a mass of four or six sides: so that, from the appearance, a person accustomed to see crystals can distinguish to what class they belong. The common rule of crystallizing salts is to evaporate the fluid very slowly till a pellicle appears at top, and then set it by to crystallize. If we proceed till the salt begins to congeal when warm, the crystallization will be incomplete and irregular. It will be proper to filtrate the liquor, to free it from impurities, before we set it aside to crystallize. If the whole of the salt is not thrown down in the first operation, it must be repeated. The crystals are always better when large, than when small quantities are made. A circumstance, however, often attends this which is very troublesome, viz. what is called the vegetation of salts. If we set a glass vessel containing a saline solution in a cool, still place to crystallize by slow evaporation, as soon as it begins to shoot it will be attracted by the sides of the vessels, and be protruded upwards in the form of a hollow cylinder. As soon as it reaches the top, it will bend down and creep along the outside of the glass, till it becomes a sort of siphon, by which the solution, as the salt is spongy, is drawn over the vessel; so that, unless we carefully watch it, we shall lose all except what was crystallized.

This phænomenon depends on capillary attraction. The prominent surfaces of the crystals first formed round the sides, draw up the solution, and then expose it to a quicker evaporation. Hence an addition of projecting crystals, which, proceeding in the same action, form a series of irregular capillary tubes, always full of the solution, and always lengthening, till a siphon is formed, by which the remainder may even be drawn out. All this may be prevented by slightly greasing the inside of the vessel above the liquid.

Enthusiastic chemists, observing the concretion of salts shooting into such fantastical figures, formerly imagined that the salts still retained the vegetative powers of the plants from which they were produced, and supposed even that they saw the form of the plant in the crystals; but all this is absurd. The best vessels to set solutions to crystallize in are those of a globular form, the edges converging at top, as that of an old retort with the neck broken. The process of crystallization is not only employed in separating salts from water, but sometimes from one another, where they have no remarkable attraction for each other. If two different salts are dissolved in the same fluid, by applying a certain degree of heat, that salt which has the least attraction for water will, on some of the water being dissipated, crystallize first, and leave the other suspended. In this manner, by repeating the evaporation and crystallization, the whole mass of the salt may be separated.

Salts have generally been treated by chemists under the form of crystals, and under this state are the most remarkable; but this is not the most simple state of salt. Crystals abound with water: sulphat of soda contains one-third water; hence the phænomenon of their *watery fusion*, *efflorescence*, and *decrepitation*. Crystals put in vessels over a fire soon assume the form of a watery fluid; for the water they contain is sufficient, when heated, to dissolve them: if the heat is increased, the water will boil with violence till it evaporates, a salt will then be formed that has lost much of its former weight. This dissolution is called the *watery fusion*. It generally happens at the same degree of heat at which water boils, and must be distinguished from the true fusion of salts, which takes place after the water is evaporated.

Efflorescence takes place when the crystals, being exposed to the dry air, lose their transparency and crystalline form, and fall into *white powder*, as happens to sulphat of soda, &c. The reason of this is, much of the water evaporating, the rest is not sufficient to preserve them in the crystallized form. But this does not happen with those crystals that do not contain so much water: these will require a brisk heat to render them fluid; the quantity of water contained in them is small; and when separated, by being converted into vapour, the crystal will burst with a kind of explosion, as we see on throwing common salt into the fire; and this is called the *decrepitation* of salts.

The first theory of the crystallization of salts was, that the form of crystals was the form of the ultimate atoms of salts, and that by a regular combination of these atoms the large masses were produced. There are many difficulties in supporting this supposition; the form of the ultimate atoms being the same as that of the crystals may be understood of some salts, but of many crystals it cannot. Thus the crystals of saltpetre are prisms of six sides, and then its ultimate atoms must have only three sides. The particles of many of the salts are not in contact with one another, as the interposition of the water they contain must effectually prevent the union of these particles; the shape of the crystals cannot then depend on the particles of salt touching one another, as in sulphat of soda, alum, sulphat of iron, &c. But, in fact, crystallization is not peculiar to salt, for there are no bodies which do not show some tendency to it in their passage from a fluid to a solid state; as when they have been dissolved or melted. Thus, if melted metallic substances cool slowly, they always show a tendency to crystallization. Some have regular figures, and appear like knots, trees, &c. Many metals have oblong masses that resemble those of salt, but are more compact. Even water, which some have thought consisted of little spherical particles, has a disposition to crystallize: its icicles are oblong masses, always determined and regular in their form, and have certain angles which they always affect. Thus, if we expose water in a bason to be frozen, the icicles always run in the same angles, and are joined to each other at the same angle, not unlike the vanes of a feather, or the leaves of many vegetables. Sir Isaac Newton, from his idea of the regular manner in which salts are deposited in *rank* and *file*, as he called it, thought that the crystals being deposited from the water in a regular manner naturally assumed regular forms; but this is not a sufficient account of the matter. The crystallization of all substances is, in fact, now agreed to proceed by the successive deposition of moleculæ, or very small particles, in series, the increase or diminution of which by one, two, three, or more moleculæ at a time may produce great variety out of the same primary forms.

It was formerly common in medicine to talk of the pointed particles of salts, and to say that they cut and stimulate in consequence of their mechanical forms when taken into the body. But what greater reason have we to suppose that the particles of salt have any more these forms than the particles of water? Salts probably produce their effects in consequence of their attraction for the animal fluids. The solvent power of every fluid is in proportion to the different degrees of attraction it has for different substances. All the various kinds of salt might be equally mixed with water, if their attraction for water was equal. In many cases, water being saturated with one salt will take up a portion of a different kind. If to water saturated with nitrat of potass (saltpetre) I add common salt, the water will dissolve more of the saltpetre. This has been thought an uncommon phænomenon; but from this fact I infer that these salts have a small degree of attraction for each other, though this does not appear on any other occasion. Many of the saline substances have a strong attraction for each other, and afterwards unite very closely; others do not act strongly on each other, and may be easily separated after union.

If we desire to separate salts in solution, we make use of three means, according to their difference of *volatility*, *solubility*, and *crystallization*. If the salts differ in volatility, we put them in a retort, and obtain the more volatile. If they differ in solubility, we may partially evaporate the solution, and thus the less soluble may be taken out in crystals. Saltpetre, for instance, frequently contains much common salt. Dissolve the salt in hot water; as the water cools, the saltpetre falls separate from the common salt, for the heat of the water keeps much more of the saltpetre dissolved than when cold it can do. Another way is this: dissolve the salt in water, and put the water on the fire till much of it has evaporated; the common salt will then fall, whilst the saltpetre is dissolved; for the heat of the water will keep the saltpetre suspended when it will not suspend common salt. Common salt does not dissolve more easily in hot water than in cold. When the water cools, the saltpetre will be deposited. Evaporate the water again, and so all the salts will be alternately deposited.

If one of the salts is deliquescent, and we are indifferent about it, we may set them on a spongy paper, which sucks up the deliquescent salt as it liquefies.

If these methods do not answer, the only remaining one is crystallization. The separation, by crystallization, depends upon the different form of the crystals, when we pick them out, and separate such as differ in form, and assemble such as agree. This means of separation is not so perfect as the others. Few of these methods of making a separation answer the first time of performing them: as in the separation of common salt from saltpetre, the saltpetre sometimes still contains a portion of common salt, which makes it necessary to repeat the operation. From common salt we may generally obtain a quantity of saltpetre; and sometimes we must crystallize it three or four times before we have it pure.

Notwithstanding all salts are, as we have seen, compound bodies, yet a distinction was established by chemists; and some, such as the alkalies and acids, were called *simple* salts, because as salts they were really so, though they might be compounded of other matters: the others, which are a combination of two salts with each other, or of some saline substance with another matter, they have termed *compound* salts; such are the combinations of the acids with alkalies, earths, and the oxides of metals. Later chemists have wished to confine the term salts to these last only. It will, however, facilitate the matter to the student to treat them in some measure according to the old system, which will at least be always necessary for the methodical arrangement or classification of salts, even if we exclude from that denomination the pure acids and alkalies. I shall therefore first take a short view of what are called the simple salts, which are divided into the two orders of *alkalies* and *acids*.

Of alkalies there are only three—soda, potass, and ammonia. The characteristic common to them all is, that a very small quantity of them, added to an infusion of *red* or *blue* coloured vegetable substances, turns it *green*, or abolishes the reddish cast of the purple. The strongest alkali produces the strongest green. Alkalies are hot and pungent to the taste, have a great degree of detergency, and are very corrosive applied to animal substances.

Soda and potass are the oxides of peculiar metals, which, like mercury, continue in a fluid state in the ordinary heat of our atmosphere, but of their other properties little is known. They have a near relation to each other, yet they are distinguished by the names of the mineral and vegetable alkalies, as before remarked. When pure, they are dry and solid substances, of a white colour. They are so caustic that they cannot be handled without injuring the skin.

Soda has all the general qualities of a salt; it requires a strong heat to make it melt; it is easy to crystallize. These crystals, from the large quantity of water they contain, which adheres loosely to them, and is generally about one-half of their weight, are liable to spontaneous calcination or watery fusion. If the water is quite evaporated, there remains a white saline crust, which may again be dissolved in water and crystallized.

This salt has been the longest known of any: it is this we find recorded in history under the name of nitre. We are told it is to be found in Egypt, in pure crystals, also in Persia, where it appears like hoar-frost: we do not, however, meet it so in Europe. We sometimes, indeed, find some particles of it pure in mineral springs, also on the surface of new walls, in the form of a damp or dewy efflorescence; but here, as well as in mineral springs, it is only found in small quantities. In a compound state it is found in abundance. Common salt is a combination of it with muriatic acid; and this is found in such quantities in the bowels of the earth, that it thence derived the name of fossil salt. The soda which is used in the arts is prepared from the ashes of sea plants; that which is in greatest perfection comes from the Mediterranean. The sea plant which yields it most plentifully is called kali, and by the natives soda; hence its name. Soda is used in the manufacture of soap, and of glass, in bleaching, dyeing, &c. In commerce it is often called by the name of barilla.

Potass, which is the other fixed alkali, agrees in several circumstances with the former: it is acrid when applied to the tongue; requires as great a degree of heat to melt; and in a very strong heat flies off totally in vapour. It differs from soda in having a much stronger attraction for water, dissolving more readily, and in less quantities, in general not requiring more than an equal weight of water. Its union is attended with some heat, and this is thought a proof of its strong attraction for water. It is deliquescent, and requires more heat to expel the water than soda does. The vapour expands very violently, and we must be careful that it does not boil over. It is generally evaporated to dryness, and has been commonly supposed not to assume a crystalline appearance. Saturated, however, with carbonic acid, it readily shoots into rhomboidal crystals more solid and permanent than those of soda. The potass used in commerce is usually a carbonat of potass, and it is proved that its combination with carbonic acid deprives potass of its caustic quality. When treated with quick lime, the lime has a stronger attraction for the carbonic acid, and consequently takes it from the carbonat of potass, which by that means is rendered exceedingly caustic. The same happens to soda. Carbonic acid renders it mild, as it is called; that is, deprives it of its causticity.

Potass has been found in a compound state only in one salt, viz. nitrat of potass (*nitre*), from which, by a particular process, it may be obtained. It is, however, procured in large quantities from the ashes of land vegetables, by infusion and evaporation, particularly from those of wood, in those countries where wood is the common fuel. It is converted into what is called *pearl-ash*, by extracting first a strong tincture from the ashes by water, which is called a *lye*. The watery parts being evaporated, a mass of a brownish colour remains, which is calcined to make it whiter. Some use another method, in order to render it more fixed and less deliquescent, which is done by steeping fresh vegetables, particularly bean-straw, in the lye already described, and then burning them; the ashes so produced are called *pot-ashes*, and are prepared in Russia, and on the coasts of the Baltic. Many uses to which potass is applied do not require it to be very pure. It is also easily obtained from a vegetable substance called tartar, and when prepared from this it was called *salt of tartar*, which when exposed to the air is deliquescent, and for that reason was formerly called oil of tartar. It has much the same qualities and uses as soda.

Long since, while the two fixed alkalies were only suspected to be compound bodies, the *volatile*, or AMMONIA, was proved to be such. It is indeed a combination of nitrogen or azote with hydrogen, and a hundred parts of ammonia contain about eighty parts of nitrogen and twenty of hydrogen. This has been shown by the experiments of Berthollet, of Dr. Austin, and many modern chemists, who have not only separated ammonia into its component parts, but have recomposed it from a union of the two ingredients.

Ammonia has been long known in commerce under the names of volatile alkali, volatile salt, and spirit of hartshorn. Its volatility is such, that under the ordinary pressure of the air it is constantly flying off in vapour, which, though we cannot see, we are sensible of by the smell. Its acrimony does not produce its effects so constantly as that of the other two; for, if applied to the skin of an animal, the heat soon causes it to fly off in vapour; but if confined by an adhesive plaster, it has the same acrid effects as soda and potass. It has a considerable attraction for water, and sometimes crystallizes; but the crystals cannot be easily separated from the water, the alkali being more volatile than the water, and being converted into vapour before the water. We must therefore have recourse to the retort, and distil the solution when we want to separate the alkali from the water. In the first operation we can perhaps obtain one-half of the alkali; and if we repeat it, we shall obtain it complete and solid.

Ammonia is sometimes produced by a natural process, as is easily discoverable in large stables which are kept close, where it affects even the eyes on entering. There is indeed always a considerable quantity in the air, where there are a number of animals together. This is proved by exposing to the air any salt that has a strong attraction for it. It is only met with in a compound state in nitrat or muriat of ammonia, the latter of which is the common sal ammoniac, and the former is sometimes found in the neighbourhood of volcanoes, or coal-mines that have burnt for a long time. For use, the volatile alkali is chiefly produced from animal substances, particularly bones, or from soot, and *putrefied vegetables*; but it is most convenient to prepare it from the hard and horny parts of animal substances. The horns of deer were formerly used, hence it obtained the name of *salt of hartshorn*; when obtained from soot, it was called *spirit of soot*. The volatile alkali is easily separated from the others in sal ammoniacs; hence the purest volatile salt is procured from sal ammoniac, and hence it was called volatile sal ammoniac.

The alkalies are of very extensive use in the arts, particularly in bleaching and soap-making, from their detergent or cleansing quality, which is the result of their attraction for oily matter, for dirt or foulness is generally some matter united with grease or oil of some kind or other.

Soap consists of an alkali, almost always one of the fixed alkalies, united with oil or fat. If either of these substances be boiled with a strong lye of potass, the oil or grease, which commonly repels water, now, by the intervention of the alkali, mixes readily with it. Potass alone, however, only produces a soft soap. In order to obtain hard soap, the compound is boiled in water with a quantity of muriat of soda (common salt). The explanation of this process depends on the doctrine of affinities. The muriatic acid has a stronger affinity for potass; it therefore takes a part of that substance from the oil, and gives it in exchange the soda with which it was before combined. This consolidation of the soap enables the manufacturer to get it easily clear from the water, for it now forms a curd on the surface of the fluid, which may be drawn off from under it by a pipe at the bottom of the vessel.

More salts are referred to the class of acids than to that of alkalies; but at present we shall turn our attention to the three principal mineral acids, called mineral because originally extracted from mineral substances; these are the *sulphuric*, *nitric*, and *muriatic*. The only form in which we can obtain them is in that of a watery fluid. In this state they must be considered as volatile with respect to other salts, as the most fixed of them does not require above 600 degrees to convert it into vapour; the others become volatile with a much less degree of heat. They have a greater attraction for water than potass, or any other substance. Their union with it is attended with great commotion and heat; though when mixed with ice or snow they produce cold. The nitric acid produces the most intense cold. Some have imagined that the sulphuric acid produces heat with ice; but they have deceived themselves in making the experiment, by mixing too much acid with the ice. No more acid should be added than what is necessary to liquefy the ice; for, after the ice is melted, the acids produce heat in proportion to the quantity of acid. When diluted with water, the mineral acids can only be distilled to a certain degree of concentration. It is plain they have a disposition to solidity, and that the reason of their fluidity is their strong attraction for water, and the great difficulty of separating it from them.

The sulphuric acid has been crystallized by a great degree of cold. The regular crystallization depends on a certain degree of strength, 1·78 specific gravity, and is favoured by the mixture of another acid, as the muriatic or nitric. It shoots into fine crystals in this case, in a temperature several degrees above the freezing point. The crystals are rhomboids, like those of carbonat of soda, and liquefy at about 45°.

The nitric acid is always congealed into a number of spiculæ at four degrees below 0 Fahr. We have no account of the congelation of the muriatic acid; but it is highly probable that it would also congeal.

Another general property is, that they change the colour of blue and purple vegetable substances into a bright red; and this they do, though the infusion has been changed into green by an alkali. If the change has been recently produced by an acid, the infusion may again be made green by an alkali, and so on alternately. It is common to deepen the colour of conserve of roses by adding a little acid, by which the conserve appears richer than it usually is.

A further property is, they readily unite with alkalies, and when the alkali is what is called mild (that is, in the state of a carbonat, or combined with carbonic acid) produce great effervescence; the reason of the effervescence is plain, as it is caused by the expulsion of the carbonic acid in the form of gas. Acids also unite with metals, lime, &c.

Lastly, the mineral acids show a remarkable degree of acrimony or corrosiveness when applied to animal substances. If taken internally, in their strong state, they are poisons; if externally applied, they give pain like burning, and destroy the part; if diluted, they prevent fermentation and putrefaction, are astringent, &c.

Some of the vegetable acids are so mild that they may be safely taken into the stomach. You will remember what I have laid down as the third canon of chemistry, That all acids are combinations of other substances with oxygen.

1st, *Sulphuric* (formerly called vitriolic) acid announces its origin by its name. It is a combination of sulphur with oxygen, and is obtained by burning sulphur in air, or with any substance containing oxygen. In the great way a chamber is prepared lined with lead, on which metal the sulphuric acid does not act. The bottom of the chamber is a large leaden cistern containing water. In this place sulphur is burned, together with a quantity of common nitre, which is necessary to supply the oxygen, the chamber being closed from the external air to confine the vapour. The sulphur and oxygen rise in the form of sulphurous gas, which is absorbed by the water, and when it is of sufficient strength it is drawn off into large glass vessels. The superfluous water is afterwards expelled by placing these vessels in a sand-bath till the acid is sufficiently strong: for the sulphuric is one of those acids which are called *fixed*, because they do not like vinegar rise in vapour with heat. The sulphuric acid, when pure and as strong as possible, is clear and heavy, its specific gravity being to that of water as eighteen to ten. From its having less fluidity or mobility, and an appearance of sluggishness, it has been improperly termed oil of vitriol. It is not volatile, and being more fixed, than water, emits no fumes under the ordinary heat of the air, and therefore has no smell. Its violent attraction for water often breaks the vessel in which they are mixed, by the heat. It also attracts from the air on the first day one-third of its weight of water, and in six days more than its weight. This depends, however, on a large surface being exposed to a moist air. Its attracting more copiously at first, shows that the attraction of the acid for water diminishes as it approaches nearer saturation. When we add water to dilute this acid, it sometimes becomes milky, and a whitish powder falls to the bottom. This phænomenon happens on account of its impurity, for the pure vitriolic acid when mixed with pure water has no such appearance. The water may in a great measure be separated by distillation, but not in open vessels, as we should then lose part of the acid. When put into a retort, the first vapour that rises is pure water. In proportion as the water diminishes, a more violent heat of about 600 degrees is required to raise the vapour, which contains more and more acid, till at last what comes over is as strong as what remains behind. The less water there is, the greater attraction this acid has for it; so that at the last a quantity of water remains united with it, which it is not in our power to separate. The process must be repeated till it is made of the standard strength, which is known by its weight, being to that of water as eighteen to ten. If we require it very strong, the separation must be very slow.

If a drop of sulphuric acid falls on clothes, it seems at first to have no effect; but after a few days the clothes break into a hole, which constantly enlarges for a long time: the reason is, that the acid takes some time to dissolve the particles of the cloth; when it has dissolved them, the action of it continues till the alkaline salts it meets in the air destroy its effect. When mixed with Florence oil, the sulphuric acid acts upon the oil, so as to form a dark viscid substance, like tar, producing a considerable degree of heat, and a vapour in smell resembling brimstone. The oil will afterwards dissolve in water.

There are other oils on which it acts with more violence, as the aromatic or volatile oils. Thus, if to oil of turpentine (which is better for this experiment when thick by standing) the sulphuric acid is added, it boils with violence, and very noxious fumes are produced. A black tough substance is the result of this mixture. Two ounces of each of these ingredients shaken together in a corked phial, became instantly hot, and, being set down, forced the cork, and every drop passed out with a hissing noise, forming a very thick dark cloud, from which fell a strong acid, bituminous *rain* all over the room.

Uncombined with oxygen, you have seen, sulphur wants the acid properties: it is quite mild and harmless, and proves a safe and salutary medicine. The acid attracts water violently; but sulphur is incapable of being combined with water, unless we add something that has a great attraction for water to it: the activity of it therefore wholly depends on its combination with oxygen. This is indeed the case with all those radical substances which are the bases of the acids. Sulphur, however, possesses some of the properties of the acid, though in a low degree. It has an attraction for alkalies; for by mixing potass and sulphur, both in powder, and pouring boiling water upon them, they act upon each other, and the sulphur is rendered soluble in water. The mixture always turns the water to a deep colour, yellow, green, or a deep red (the solution of the alkali alone would have been colourless), and it has the smell of rotten eggs, or the scouring of a gun, which scouring of a gun is produced from a sulphuret of potass, the more volatile parts being sent off in the explosion, gunpowder being a composition of nitre (nitrat of potass), sulphur, and charcoal. The oxygen of the nitre uniting with the charcoal, forms carbonic acid gas, the nitrogen of the nitre is disengaged, which all go off in an aërial form on the explosion; and the fixed part, the potass, uniting with the sulphur, forms a sulphuret of potass. If the alkali and the sulphur are mixed together in a dry form, and a sufficient heat is applied, when they begin to melt they unite with effervescence, and the produce (sulphuret of potass) was formerly called *hepar sulphuris* (liver of sulphur), from its resemblance to theliver of animals. Soda will form a similar compound.

The sulphuric acid may be obtained from sulphur, by spreading the sulphur on a plate, and covering it with a glass bell, the inside of which is wetted with the dew of hot water; the sulphur being inflamed, the vapour arising attaches itself to the dew. This process has been already explained.

It has been supposed that the sulphuric acid exists in the air: the only argument for which opinion is, that on exposing an alkaline salt to the air it is said to attract a quantity of the acid. But there are no accurate and well-attested experiments to prove this, but rather the contrary. Neumann, the most curious and exact chemist of his age, did not find sulphuric acid in rain- and snow-water: the place where it is really found is in the bowels of the earth, and in mineral waters disengaged from every substance but water, but in very small quantities. It is found compounded with other substances, as ores of metals, gypsum, &c. Its uses are in pharmaceutical operations, dyeing, bleaching, hat-making, &c.

Brewers also find it the most effectual means of cleansing their foul casks. It is common to see them burn a small quantity of brimstone in their empty casks, which fills them with sulphurous acid gas, and thus effects the purpose.

The *nitric* and *muriatic* acids are so named from the two salts, nitre (nitrat of potass) and common salt (muriat of soda), from which they are always prepared. In their strongest state they are not so heavy as the sulphuric acid, therefore are said to contain more water and less salt. They are more fixed than water, requiring a little more heat to convert them into vapour. Yet we have reason to think that the saline substances of which they are composed are very volatile; but they seem depressed by the water; and it is remarkable that a strong acid is more fixed than water, though composed of water, and a salt more volatile than that fluid. If heat is applied to these acids, they fly off in elastic vapour, which it is impossible to condense, any luting, or even the vessels themselves, being burst by it. If, however, we throw a small quantity of water into the receiver, the vapours are immediately absorbed by the water; yet if we continue the heat, the elastic fumes again arise. The more water we add to these acids, the more we depress their volatility: they may, when diluted, be concentrated, but not so much as the sulphuric.

The *nitric* acid, which is a combination of nitrogen or azote (the impure part of our atmosphere) with oxygen; in the proportion of thirteen parts of nitrogen to eighty-seven of oxygen, is a fluid of considerable weight, but not quite so heavy as the sulphuric. In its strongest state it is *white*, but the action of light by developing some nitrous gas gives it an orange colour, and then, when exposed to the air, it constantly emits fumes, the quantity of acid it contains being greater than the water can repress, and these fumes are noxious. It *flames* with oil of turpentine. In this experiment add a little sulphuric to the nitric acid, which increases its effects. Many other oils would succeed without the sulphuric acid, as oil of cloves. The acid ought to be recent, for if long kept, or in bottles not tight, it loses its power.

The nitric acid emits fumes which tinge the air the same colour as itself, especially the air in the bottle with it. It readily attracts water from the air: but when the water is added in any quantity they unite with violence, producing heat and copious fumes. The colour of the acid is changed to a green, and sometimes to a blue, and upon the addition of more water, the green gradually disappears. Some have attempted to explain this phænomenon by saying that the colour is owing to a small quantity of copper combined in the nitric acid, for saline liquors are found to produce a green colour with copper; but this is not the case. This colour on mixing the acid with water is not an inseparable quality.

It was mentioned (Lect. XXVII.) that there are two states in which this acid appears: 1st, The *nitric*, or the base fully saturated with oxygen; 2dly, The *nitrous*, or the nitrogen combined with a smaller proportion of oxygen.—Such is the aquafortis of the shops, which is not only weak but impure. It is, however, a substance of considerable importance in the arts, particularly in dyeing, etching on copper, and assaying ores and metals. Nitric acid in its strongest state, is even more corrosive than the sulphuric.

This acid with ice or snow is used to produce one of the freezing mixtures. There is no difference between snow and ice in the effects, except that the snow being more divided, gives a greater extent of surface for the acid to act on. Such an intense degree of cold is produced by the mixture, that if the glass is breathed upon, the breath is instantly frozen, and forms a hoar frost. The same colour takes place on the snow being dissolved, as when the acid is mixed with water.

The nitric acid is found in very small quantities in the air in the real acid state. But in fact, the whole that we possess comes originally from the atmosphere; for saltpetre, or nitrat of potass, whence it is prepared, is obtained by *lixiviating* (or washing) earth and rubbish which has been long exposed to the joint action of the atmosphere and animal effluvia. Yet it appears to be the impregnated calcareous matter that determines the formation of the salts found in it, and not an acid ready formed that finds out and seizes the former.

3dly, The *muriatic acid,* in its strongest state, is a light-yellowish-coloured fluid, and emits fumes when exposed to the air, which do not tinge the air red, but impart to it a mistiness. These fumes are noxious to the lungs. Its smell resembles that of burning soot.

The radical or base of the muriatic acid is at present unknown in any other form. It is of course as an acid combined with oxygen. It is more volatile than the nitric, is not near so heavy, and upon mixture with water produces not so much heat. This acid is only produced for use from common salt.

There is a modification of the muriatic acid, which, on account of its singular properties and important uses, must not be passed over. It is the oxymuriatic acid, or the muriatic radical still further oxidized by distillation from manganese, a mineral substance abounding in oxygen, and which parts with it readily in this process. For this discovery we are wholly indebted to the illustrious Scheele, who also demonstrated all its most striking properties. It arises from the mixture in the form of gas or vapour of a yellowish-green colour, which is readily absorbed by water, consituting a liquor not acid, but astringent, to the taste, yet approaching more nearly than any known fluid to the character of a universal solvent, few substances being exempt from its action, and gold, which resists so many menstrua, yielding immediately to this. The gas is exceedingly acrid and penetrating. It kills animals which respire it, but supports combustion even better than common air in many cases, and sets fire to various combustibles, and even metals, when plunged into it in a dry and divided state.

It rapidly destroys vegetable colours without turning the blues to red. This property it retains in the liquid state, and combined with the alkalies or lime. It is accordingly become an instrument of the utmost value, under judicious management, to bleachers, who are able by its aid to accelerate at will that long process of oxygenation, by which the joint powers of light, air, and water, slowly and imperceptibly extracted from the fibre of linen and cotton their original dusky tinge. With the alkalies it forms salts of equally singular properties.

There are also other acids derived from the mineral kingdom: as the arsenic, tungstic, molybdic, &c. which are only metals oxidized, and their properties as acids not important.

4thly, The *boracic* (formerly called sedative salt, from its supposed medicinal power, and which, with soda, constitutes the well-known salt borax) is perhaps more properly entitled to the name of a mineral acid. It is obtained only from borax, which is imported from the East Indies, and of the origin of which we have very little account. The method by which it is extracted is such, that it has no other form than crystals, which are composed of very fine small flakes adhering slightly together; they feel smooth and slippery, and are remarkably light. From some experiments we might conclude that some part of the salt is volatile, and some fixed; but in reality none sublimes, but what is carried off with the particles of water. If to the crystals we apply heat, the first effect is an exhalat on of a little water with a quantity of salt, which sublimes in crystals of thin plates much finer and thinner than before; what remains endures any degree of heat without being volatilized. When red-hot it melts into a mass like glass; it has the same sort of transparency, and preserves it when cool: it may be again dissolved by pouring cold water upon it, and may be afterwards crystallized. The sublimed particles returned and subjected to the same operation, put on the same vitreous appearance.

Boracic acid has but little attraction for water (*i. e.* for more than it always contains). It dissolves but in small quantities in cold, and not much in hot water; it crystallizes again when cool in little transparent whitish icicles. Its properties as an acid are very weak; it has no taste at first, but afterwards gives a sensation of bitterness. Its effects are still weaker upon the vegetable tinctures than even the vegetable acids: sometimes it does not affect them, and when it does, I apprehend it is from some other acid it contains. Tried upon tincture of roses and violets, it had no effect. Litmus (which is more delicate, being a preparation of one of the mosses used in dyeing, and which is purplish) it changed into a sensible *red*.

Boracic acid effervesces with a boiling hot alkaline solution, but not with metals or absorbent earths, though it may be united with them. It has a weak attraction for inflammable substances, particularly spirit of wine, the flame of which it tinges green; hence it has been thought to contain some copper, but we have no proof of this.

Lastly, the *fluoric*, extracted from the fluor or beautiful Derbyshire spar (which is a fluat of lime*). This acid possesses the singular property of dissolving siliceous earth, and, in consequence, corrodes glass with such ease that it soon penetrates through a thick bottle. Hence it is applied to the elegant ornamental art of etching on glass, in the following manner.—A wax ground being laid, and the design traced with a needle, the acid (kept in a leaden bottle) is poured on in a thin stratum, and remains a few hours, more or less, as strength of impression is required. Being then washed off, and the ground cleared away by heating, &c. the design is found as well executed as on copper. It is smooth and transparent: when opake strokes are required, the piece, after preparation, is placed over the vapour arising from a mixture of pounded fluor and sulphuric acid.

---

* It is extracted or expelled from the substance with which it is connected (lime in this case), as all the weaker acids are, by pouring on it sulphuric acid, which by a stronger attraction expels the fluoric acid, and seizes the lime.

The *carbonic acid,* formerly called fixed or fixable air, may be said to belong either to the vegetable or mineral class, since it exists in vast abundance, combined with chalk, marble, and limestone, from which it may be expelled either by heat or the stronger acids, and is also the invariable and copious product of the vinous fermentation. In all cases it is first set free by a strong effervescence in the form of an invisible elastic fluid, which being absorbed by water, gives it a brisk acidulous taste, and consequently is an ingredient in many, or rather most, of the spa waters. Carbonic acid gas is about twice as heavy as common air. Hence it may be received in open vessels, unconfined by water, may be poured into others like that fluid, and will with equal certainty extinguish flame, and suffocate animals immersed in it.

The base of this acid is carbon, and from its acid character it is to be inferred that the carbon is combined with oxygen. Burning charcoal affords much more than its own weight of it. The test for its presence is clear lime-water, from which it throws down the lime in the form of a white curd, which is chalk, or carbonat of lime. It is in this manner that stalactites are formed. When water holding lime in solution oozes in drops through the roof of a grotto or cavern, where there is carbonic acid gas, it is immediately seized by the gas, which uniting with the lime forms a solid ring on the surface of the drop where it is attached to the stone roof. Another drop succeeding, another ring is produced upon the former. Thus, in process of time a slender tube is formed, generally full of water, with a drop suspended from the end. The tube, however, gradually fills up, and the water then proceeding over the external surface, deposits its lime more quickly in the state of a carbonat; and thus the tube speedily increases to a stalactite. The atmosphere contains about one-hundredth part of carbonic acid gas diffused in it.

There are yet several acids referable to the vegetable kingdom, some of which are native, others artificial, products. These are the acetic, tartaric, citric, gallic (acid of nutgalls), *oxalic* (acid of sorrel), *malic* (of apples), *benzoic* (of gum benzoin). I shall notice in particular the four first.

The *acetic acid*, commonly called vinegar, is (as its name expresses, *vin aigre*, sour wine), any proper vinous liquor rendered acid by oxygen absorbed from the atmosphere. In this country the infusion of malt after fermentation is made into an impure vinegar, which being distilled becomes a clear colourless liquid, moderately acid. By freezing, and by chemical processes, this may be deprived of its water to such a degree as to constitute a very strong acid of a pungent smell, and crystallizable at 22° of the thermometer.

This acid is a production of most extensive utility, not only in diet and medicine, but in the arts. Combined with copper it forms verdigris, and with lead the salt improperly called sugar of lead. There are acetats of copper and some other metals.

If this acid is exposed to a red heat, there are soon no remains of it to be seen, unless it is united to a fixed alkali, in order to repress its volatility. If the neutral salt also produced by this mixture is exposed to a very strong heat, the acid is either burnt or destroyed, and there arises a vapour of a very disagreeable smell, in which we can discover something of an inflammable nature, but nothing like the acid. If we examine the remains of the compound, we find it a little heavier, in consequence of the substances with which it is united.

The acetic acid is to be destroyed by heat when mixed with alkali, and by itself when the heat is properly applied. There are several substances which are converted into vapour before we can give them a sufficient heat for inflammation: this is the case with spirit of wine, of which the vapour only takes fire. Now if we manage the acetic acid in the same manner, and heat it till a copious vapour arises, the vapour will take fire as other inflammable substances. No acid is to be obtained from the inflamed vapour, and nothing is left behind.

Acetic acid is a compound of oxygen, hydrogen, and carbon. 100 parts contain—

50·19 oxygen.
13·94 hydrogen.
35·87 carbon.

Tartaric acid.—After the fermentation of wine is over, there separates a quantity of a substance called tartar, which encrusts the casks. In collecting it from the cask, it is necessary to throw in a quantity of hot water, which dissolves the salt, and when the water is evaporated the salts crystallize. Rhenish wine affords tartar in the greatest quantity: when old Rhenish wine is thus depurated it is called old hock. Tartar undergoes an operation to make it fit for medical purposes. It was customary in our laboratories to purify it by continuing the evaporation till the tartar concreted in a thin saline crust at the top, which was skimmed off as fast as it appeared, and was called cream of tartar. Lees of wine contain tartar; they are deposited in the form of a muddy liquor, and are separated by decantation. They yield, by being dried, &c., a large proportion of *cendres gravellées*, as it is called in France: it is used in the preparation of ink for copper-plates, under the name of Frankfort black.

Cream of tartar, or acidulous tartrat of potass, is a compound salt, from which, by a more powerful acid, the alkali may be separated, leaving the tartaric acid free and crystallizable by itself.

Tartaric acid consists of oxygen, carbon, and hydrogen, in the following proportions:—

70·5	parts oxygen.
19·	carbon.
10·5	hydrogen.
100·	

Citric acid mixed occasionally with tartaric constitutes the native acid of most of our fruits. Great quantities of it are now obtained in a crystallized state from the juice of lemons and limes, which, together with the tartaric, are applied to use in calico-printing; for, being mixed in paste and stamped on cotton stuffs in various patterns, they either present the colour with which the ground is formed from fixing itself in that part, or dislodge it, after dyeing, at pleasure, thus leaving the imprinted part in its original whiteness. This effect results from their attraction for the metallic basis of the colour, while, unlike the mineral acids, they leave the fibre of the cloth untouched.

The component parts of the citric acid are oxygen, hydrogen, and carbon.

The malic and oxalic acids nearly resemble those which we have now specified.

Gallic acid exists ready formed in galls. It produces a black dye with solutions of iron, by uniting with that metal into an insoluble compound called gallat of iron. Hence, besides the utility of galls in writing-ink and dyeing, the infusion of galls in water or spirit is one of the best tests for the presence of iron in solutions where it is suspected, but not otherwise apparent.

Prussic acid is also employed by the chemist for this purpose.

This, which may be regarded as an animal acid, is wholly a creature of art; and the discovery of Prussian blue (whose colouring basis is prussiat of iron) was made long before we knew any thing of this acid. For the preparation of Prussian blue, a quantity of potass is calcined with dried blood till it ceases to smoke: in this process the acid in question is formed out of the animal matter employed (which is not confined to this material blood), and immediately seizes the alkali. We have then a prussiat of potass, which being dissolved in water, and mixed with sulphat of iron (green vitriol), a double decomposition ensues, prussiat of iron falls down in a precipitate, and the alkali is attached to the sulphuric acid, forming sulphat of potass, which may be washed off from the colour.

Phosphoric acid is the direct and sole product of the combustion or oxygenation of phosphorus, which consequently affords more than its own weight of it. This acid, deprived of all its water by heat, is solid, colourless, and of a glassy appearance. It has a very sour taste, without any smell; is not corrosive to the skin, and readily deliquesces.

It dissolves in water, giving out much heat, like the sulphuric.

It forms with lime an insoluble compound, phosphat of lime, which has the appearance and properties of earths, and is the solid part or base of animal bones, in which it is united to gelatine, or, in plain language, glue. Hence calcined bones, by proper treatment, yield phosphorus, the oxygen being abstracted by the charcoal employed in the distillation, which is conducted in a strong heat.

The other animal acids are the *uric* (extracted from calculi), the *rosacic*, the *amniotic*, and the *lactic*, or acid of milk.

The arrangement of the compound or neutral salts under the new chemistry is peculiarly easy. The barbarous jargon of the old school, which meant nothing, such as sal digestivus, sal mirabilis, sal polychrestis, is banished, and the name now discovers the materials of which the salt actually consists. Thus, when we hear of nitrat of potass, or muriat of soda, no person who knows any thing of chemistry can mistake; but must understand that these mean compounds of the nitric and muriatic acids with potass and soda.

The different *genera* of compound salts are denominated from the acids. Thus, we have sulphats, nitrats, muriats, borats, fluats, tartrats, acetats, phosphats, &c. But it is necessary to remind the student, that where the salt is compounded of the acid, when not fully saturated with oxygen, the compound is distinguished by the termination *ite*. Thus, the sulphurous acid produces *sulphites*; the sulphuric acid *sulphats*.

The *species* of compound salts are distinguished by subjoining the base; as sulphat of *soda*, which distinguishes the salt from sulphat of *lime*, or any other sulphat; and as some of the acids will unite with two bases, the *triple* salt is described by adding both bases, as *tartrat* of *potass* and *soda*. Where there is an excess of acid in the salt, it is expressed by prefixing the preposition super.—Thus *sulphat* of *potass* expresses the combination of the sulphuric acid with potass, and super-sulphat of potass denotes that there is a redundancy of acid. On the contrary, the preposition *sub* implies that there is an excess of base; thus sub-*sulphat* of *potass* is the salt before described, but with a deficiency of the acid, and a redundancy of the potass or base.

Salts have also been divided into the alkaline, the earthy, and the metallic, according to the nature of their respective bases. But it is unnecessary to enter into any particular description of them here, since the nomenclature itself defines the nature of the salts. Dr. Thomson calculates that there may be about 2000 different species of compound or neutral salts; and he remarks that "some idea may be formed of the progress which this branch of chemistry has made, by recollecting that forty years ago not more than thirty salts in all were known."

LECTURE XXX.

CHEMISTRY.

EARTHS.

We are led next, by the arrangement we have adopted, to consider earthy and stony substances. The common definition of these substances is, that *they are bodies not soluble in water, not inflammable, and whose specific weight to that of water is not more than four to one.* This definition, like that of salts, is not so precise as to be out of the reach of criticism, because there are some earths perfectly soluble in water, and many that are met with in the bowels of the earth that afford the greatest probability that they have been in a dissolved state. But the distinction, though not strictly just, may be proper in a looser sense; for there is a great difference of solubility between earths and salts, for a few grains of earth are sufficient to saturate a large quantity of water, and even these dissolve less perfectly than salts. There are two other circumstances, not included in the definition, that make part of the idea of an earthy substance. 1. A great degree of fixedness. 2. A disposition to assume the form of a glassy concretion when melted. By the first of these they are distinguished from all the other objects of chemistry, for we cannot in general convert a pure earth into vapour. The second characteristic is indispensable to an earthy substance, and in a great measure peculiar to this class. The bodies which come under the class of earths are nine in number, viz.

1. Lime.
2. Alumina (or clay).
3. Silica, or Flint.
4. Magnesia.
5. Barytes.
6. Strontian.
7. Yttria.
8. Glucina.
9. Zirconia.

Some of these earths are much more plentiful than others, and the great mass of this globe may be said to be composed of lime, flint, and clay, variously mixed and disposed in the different species of stony bodies.

The surface of the earth evidently consists of a confused mixture of decayed animal and vegetable substances, and earths rudely united together; but when we have got below the surface, we find the materials of the globe arranged in a regular manner. Sometimes, indeed, we find heaps of stone, which do not consist of layers, but are confused masses of unequal thickness; these are called rocks. The strata are in general extended through a whole country, and perhaps through the globe itself. Thus, in digging for coal, the workmen first come to a bed of clay, next to a bed of sand, for the thickness of which there is no particular rule; then perhaps to a bed of freestone; and, lastly, to the coal. After they have wrought the coal, they are obliged to sink another pit; and in this they find the same strata of the same thickness as above. These extensive bodies are found most regular when the country is flat, being generally parallel to the horizon, though frequently dipping downwards in a certain angle. In many places the beds have a wave, as where the country consists of gently rising hills and vales: here too they generally dip. In riding a mile, we perhaps pass through ground composed mostly of sand, in another mile, perhaps of clay; and this is occasioned by the edges of the different strata lying with an obliquity to the horizon. The projection of the edges of other strata is called by the miners *cropping*, and where the edge shows itself, the *crop*. By the same kind of projection, mountaius, or ridges of mountains, are produced, and the form of them regulated. Mountains are said to have a back and a face; the latter smoother, and the former more rugged. We generally find too on one side of the mountain a more gradual ascent than on the other, which is occasioned by the cropping of the strata. The back of the mountain shows the obliquity with which the strata sink into the ground; the abrupt edge of the strata, however, becomes more sloping as time, producing a decay, draws rubbish from above. Where the face of the country is irregular, this appearance depends on the different hardness or softness of the strata. The abrupt rocks which we see in many parts seem to have been composed of an adventitious mixture of different strata, which have resisted the injuries of time with unequal force.

This is a general view of the materials of which this globe is composed. A variety of hypotheses have been adopted to account for it. In general, it has been supposed that the strata originally lay horizontally, and were formed by a deposition from water. The arguments for this opinion are forcible. The relics of a variety of substances, which we now find only possessing the watery parts of the globe, are found in rocks and mountains at a very great distance from the sea. In strata of limestone, often very distant from the sea, we find the remains of shells, &c. the production of the ocean. Other circumstances prove that the sea has covered parts of the earth, which are now at a great distance from it, and that the various directions which the strata now have were not their direction at their first formation.

Some have attributed this irregularity to frequent earthquakes; others have imagined that the globe before the deluge contained an immense body of water, covered over with a crust of earth, which at the deluge was broken in pieces and sunk in the waters; others, in a more extraordinary manner, have thought that the earth in its revolutions has some time or other received a stroke from a comet, which has thrown all into confusion. Buffon supposes that the sea is continually changing its bed, and is constantly washing away the ground from one place to another.

Not to enter further into these hypotheses, I shall only observe, that these strata are often broken in different directions, in general perpendicularly, so that the parts of the different strata are separated from each other. The wideness of these rents is different, sometimes a few inches, sometimes many yards. They are very commonly filled up with substances different from the composition of the strata. You may have observed in mountains the appearance of a white stone, which passes through it like a vein. This has been a rent filled up with a particular kind of stone. These are also very common in the strata of coal. When met with in the strata they are called veins. They are generally of a considerable hardness; and in these the metallic substances are generally found. Where any of them are not filled up with extraneous matter, the internal surface is set with very beautiful and regular crystals, called spar, projecting into the cavity.

1. The forms under which *lime*, or calcareous earth, appears, are various, but all agree in mildness and insipidity, and hardly show any degree of solubility in water: they all effervesce with

acids, and show the same kind of relation to acids that alkalies do: they have the same attraction for the acids, and the same affinities.

The compound of lime, and an acid after saturation, has no acrimony or acid taste: it produces no effect on vegetable infusions. Lime is found purest in limestone, marble, and chalk, which only differ in their degree of purity, or in the manner of their aggregation admitting more or less polish. The coarser limestones contain other substances besides the calcareous earth. The different coloured veins in marble are produced by the admixture of other substances, unequally distributed through the mass.

Freestone may be mentioned as another kind of matter, which contains a considerable quantity of lime. The principal ingredients of freestones are sand or gritty particles cemented by some other substance, which is most frequently lime; these are often found in extensive strata in the bowels of the earth.

2. Lime is often found in the veins of rocks and crevices of mountains, combined with fluoric acid, and in this state it is called spar, or, more properly, calcareous spar, to distinguish it from others. The English lead-mines are full of spars; their shape is generally a firm column, terminated at each end by a pyramid.

3. It appears in the form of vegetable and animal substances petrified into stone, by being exposed to petrifying waters. These fill up the

pores of the substances with lime, commonly in a state of combination, as carbonat of lime, and incrust them. Hence we may conclude that this earth is soluble in water, and deposited in the bodies of other substances. The quantity of earth, however, contained in the water is very small, and for that reason the petrifactions are formed very slowly.

4. The shells of all crustaceous animals, from the coarsest to the pearl which lines the shell of an oyster, are all composed of carbonat or phosphat of lime, and perhaps a small quantity of gelatine, or animal glue, a viscid fluid, which at first issues from the body of the animal, and at last acquires great hardness. Egg-shells are of the same nature, and those marine bodies which, from their hardness and vegetable appearance, are called stony plants; such are all the species of coral, which are the work of small animals of the polypus kind.

5. Marls, which are generally divided into three kinds:—1. The shell marl; 2. Clay marl; 3. Stone marl. The first is found in beds of considerable extent, and consists of the remains of sea and land shells: that which consists of sea shells is generally found in the greatest quantity. Of this kind is that of Paris, mentioned by M. Reaumur, which is about ten feet deep, and of great extent, consisting of oyster and other sea shells. The relics of land shells are those of snails: they have probably been carried off by the current of some water, which being drained

off, the shells remain behind. Beds of fresh water shells are also found. Clay marl is a calcareous matter, which, on being exposed to the air, crumbles into dust. It is to be distinguished from common clay by effervescing with acids. Stone marl differs from clay-marl only in being much harder; but it differs from stone in breaking to pieces when exposed to the air. Most of these species of calcareous earth derive their origin from shells. Marbles are frequently formed of shells, and those of Derbyshire exhibit this appearance in a remarkable manner.

Lime, under most forms, may be known by effervescing with acids, and being entirely soluble in some of them; as the nitric and muriatic for instance. It is proper to remark, however, that farmers and other unskilful persons have sometimes supposed certain earths to effervesce with an acid; when what they mistook for effervescence was the rising of the common air that was separated from the mixture, which would have been the case if the earth had been thrown into water. We must, therefore, when we try the experiment, always pour a little water on the earth, which being imbibed into the pores, expels the air, and makes a kind of effervescence. If, after this caution, on the addition of an acid, effervescence takes place, we may be sure it depends on the presence of lime. We may know whether limestone or marl is good, by observing whether one-half or three-fourths dissolves in the acid, as they dissolve in proportion to the lime they contain.

The sulphuric acid attracts calcareous earths with great impetuosity. When it is added to chalk, we shall find the earth not dissolved, but settling by degrees into a sediment more bulky than the chalk itself. The reason of this appearance is, that the chalk, though united with the acid, has very little solubility in water, one pound weight of water being necessary to dissolve a few grains. When the chalk settles to the bottom, the bulk is increased by the addition of the sulphuric acid. The compound thus formed is sulphat of lime; formerly, and even now, vulgarly known by the names of gypsum, selenite, or plaster of Paris.

The other mineral acids unite with this earth with effervescence, and dissolve it into a transparent fluid, and the compounds are easily soluble in water.

Acetous acid forms with lime an exceedingly soluble salt. Many of the other vegetable acids readily unite with it, some of the resulting salts being soluble, others not. The oxalic acid has a peculiarly strong attraction for this earth, seizes it even from the mineral acids, and precipitates with it in an earthy form. Hence this acid is the best test for the presence of lime in solutions, as it will detect the smallest portion.

We do not find that lime melts in fire, but it is much changed by it; it becomes more friable and light, sometimes losing one-third, sometimes one-half of its weight, and from a mild substance becomes active and acrid; it is then called quicklime; and if left upon a moist animal or vegetable substance, it corrodes and in some degree dissolves it. If the lime is new burnt, however, and the animal and vegetable substances are covered with it, they will be parched up into a hard or horny mass: this is occasioned by the strong attraction which quicklime has for moisture; in consequence of which it extracts the water they contain, as is evident, for if moisture is added again to these substances, they become soft and pulpy as before. This attraction for water is one of the most remarkable qualities the fire gives it; for if water is poured upon burnt lime, it crumbles by degrees into a fine powder, a great heat is produced, so considerable as to set on fire a stick if put into it. It is therefore very dangerous for ships to take in a cargo of quick-lime.

These facts are not difficult of explanation. Lime is seldom found in a pure state, but almost constantly combined with carbonic acid in the form of chalk, limestone, marble, shells, &c., which are all *carbonats* of lime. By heat the carbonic acid is driven off in the form of gas, and the lime loses proportionably of its weight. It has then a strong attraction for water, which, when poured upon it, forms a real combination in a solid form. The condensation of the water sets free a quantity of caloric, and heat is produced. Since heat or fire then diminishes the weight of lime, a knowledge of this fact must be of great use to farmers, for by burning the limestone on the spot where it is found, they have much less expense of carting. A red heat is necessary to burn lime. When the mass of lime is saturated with water, every particle of the calx is united to a proper quantity of the fluid; and it is now called *calx extincta*, or *slacked lime*, which has not the same attraction for water as quick-lime, but agrees with it in every other quality. Slacked lime, though it appears dry, contains a great deal of water. The water adheres closely to it; but by a red heat it may again be separated, and the lime becomes again quick.

The attraction which lime has for water is the principal reason of its use in building; for while in a soft state it adheres to the stones or bricks as a cement, and speedily becomes solid. The solidity is increased by attracting carbonic acid from the atmosphere, so that if mortar is well made, the older it is the stronger cement it becomes.

It is not only in the state of a carbonat that lime is found in nature. It is often united with sulphuric acid; in this state it is, as before intimated, scientifically called sulphat of lime, and vulgarly gypsum.

Gypsums are found in stony masses, very soft, and easily scraped with a knife. They are distinguished from chalks and limestones by not effervescing with acids, and from other earthy bodies by being by burning changed into white powder, which, when mixed with a large proportion of water, suddenly concretes into a stony mass called plaster of Paris. They are most commonly found in the strata of clay, sometimes in those of sand, of a whitish milky-coloured mass; but the small pieces are transparent, and sometimes have a red tinge. They are often composed of small shining particles, like the grains of sugar, and when under this appearance they are particularly called gypsum. When hard, so as to be cut into toys and figures, they are then called alabaster.

The second form under which they are found is that of a fibrous structure of oblique crystallizations, which are parallel to themselves, but which cross the mass from the upper to the under surface. In this state they are called fibrariæ. These differ much in size and regularity of concretion.

The third species is composed of clear transparent plates, like glass, in close contact with each other, but which may be separated. They split with a knife into very fine plates, very flexible, though they cannot be bent without producing flaws. They are called *glacies manna*, and sometimes Muscovy glass, but improperly, as that is a different substance.

The fourth species is in the form of separate oblong crystals, and is called *selenite.* Some are long and regular, like crystals of salt.

The fifth species, or gypseous spar, is of a platey texture, and distinguished from all other bodies by its weight. The ores of metals are often found in this spar.

Sixthly, It is often met in waters of springs in a dissolved state. When the water is evaporated, it is deposed in crystals very small, and which appear like a white powder; but by the microscope are found to be oblong regular concretions.

II. **Alumina** means the earth of alum; but though the salt which bears that name was well known to the antients, they were entirely ignorant of its component parts. The alchemists discovered that it was composed of sulphuric acid and an earth; and it was afterwards found that this earth is *clay* in its purest form. Alum then is a compound of sulphur, oxygen, and clay.

Alumina may be obtained pure by dissolving alum in water, and pouring in ammonia or potass, as long as any precipitate is formed. The nature of the process must be obvious. The alkali seizes on the sulphuric acid which the alum contains, and the alumina is thrown to the bottom. This, when rendered still purer by a further process unnecessary to detail, is the real base or constituent of all clays, formerly called argillaceous earth; for all the clays which are found native are more or less combined with other extraneous matters.

Clays are among those earths which most abound in nature. There are immense strata of them, and they make a part of every rich soil. The idea which naturalists and others have of them is that of natural substances, the purest of which are firm, and have a sort of unctuosity, and which, by rubbing with the finger, receive a polish. They imbibe moisture, so that when applied to the tongue it adheres to them. From their attraction for water, they are always found moist in their natural state; if more water is added, they form a soft and ductile paste, which, when thoroughly burnt and dried, becomes hard, stony, and impenetrable to water.

As clay, when wrought together, becomes impenetrable to water, it is made use of to retain water in ponds, &c. This is the reason that when cattle are allowed to tread a clayey soil in wet weather, the plants die that grow there; for the clay being mixed with the water by their feet, the ground will be too tough for the plants to spring up in, especially when the clay, thus trod together, is afterwards dried by the heat of the sun, for then it will prevent the rain from penetrating to the roots of the plants.

Clays differ much in consistency: some melt in the mouth, others are gritty, and get between the teeth; they are white, yellow, blue, grey, or black. Some are less viscid than others. Some resist a very violent heat, without undergoing any change; but most of them, in very intense heat, melt into a vitrified mass. Some of them effervesce with acids, others not. All these varieties, as I intimated before, have but one species of earth for their basis, and are nothing more than a mixture of pure alumina with heterogeneous substances.

The variety of colour usually depends on an admixture of iron. We can actually extract iron from most of these clays, especially those that burn to a red colour, which colour is always assumed by the calces or rust of iron; when they effervesce, which is from a mixture of lime, they class with marls.

As alumina is obtained from alum, so, on the other hand, by mixing clay while it is heated in a crucible almost to redness with strong sulphuric acid, gradually affused, a very perfect combination may be effected, and plenty of alum procured by lixiviation with an addition of potass.

The quantities of alum employed in the arts are not, however, prepared in this way. Alum is sometimes met with in small quantities in mineral springs, but is mostly prepared from certain fossils, or ores of alum, as they are called. These ores are generally found in strata, which appear like indurated clays, of a dark black colour. They have a sulphureous smell: when exposed to the air for some time they grow hot, swell, and crumble down into a powder, emit fumes like brimstone, and sometimes take fire. Some do not undergo this change merely from exposure to the air, but must be first burnt or roasted, and then exposed to the air a good while before any alum can be obtained. After they have been crumbled down in this manner, they are steeped in water, an alkali is then added, and the alum crystallizes and subsides. The fixed and volatile alkalies are both employed; but the volatile alkali or fetid urine is most used, which attracts the superfluous acid.

At Hurlet, near Glasgow, there is a remarkable bed of alum ore, which, having been antiently laid open by a coal-mine carried through, is now, by long contact with the air, prepared for yielding alum, and is wrought for that purpose.

These ores, therefore, are natural mixtures of clay and sulphur, and when exposed to the air, the oxygen in the atmosphere is attracted, and converts the sulphur into sulphuric acid. After a proper quantity of alkali has been added to the solution, it is crystallized in the common manner. The crystals are at first tolerably distinct, but of no considerable size. A very strong solution being prepared from them a second time, it is put, after clarification, into large tubs, where the salt forms a foot thick on the sides, top, and bottom. The tub being unhooped, and the staves removed, a hole is made in the lower part of this crust, and the mother liquor (as it is called) flows out into a proper receptacle, leaving this artificial grotto lined and filled with large crystals of the utmost beauty, which, however, is forthwith demolished, and the fragments sent off to the purchaser.

Alum is of great use in the arts, particularly in dyeing, where it acts as a vehicle for the colour, or *mordant*, as the artists call it. It serves as a ground to fix the colours in the substance of the cloth, and is therefore used preparatory to the stuff being put into the bath, or vessel which contains the dye. It is generally agreed that it is the earthy part of the alum which has this effect, entirely independent of the acid.

Boles, red chalk, &c., are all mixtures of alumina and other matters. Red chalk has its colour from a vast quantity of iron which it contains.

III. The character by which SILICA or FLINTY earths and stones are distinguished is extreme hardness, being impenetrable to the hardest steel; they make an impression on it, and strike fire; they also make an impression on glass. They are called crystalline, because found in more regular crystals than other earths; vitreous or vitrescent, because used in making glass. They are thought purest when they are transparent and colourless; but we find flinty matter very pure when tinged of a dark colour, provided it burns white in a violent heat. This, added to its hardness, are sufficient characteristics: but it is much oftener met with impure, and hence its varieties.

It is found in strata of different kinds. Those which contain it purest are freestone, gravel, and sand: the whitest sorts are the purest. Black sand is not uncommon in America, and is generally supposed to contain gold; but the separation is too difficult to answer the expense.

Gravel consists principally of the same kind of matter, but in larger and more irregular masses, and, on the whole, is seldom so pure as the flinty matter in sand.

The stones admired under the name of pebbles are of this nature, and owe their beauty to the other materials they contain. Their external surface is rough, but their internal structure beautiful when polished. In all the white milky pebbles there is an alternate whiteness or milkiness, as in the large ones called agates. In most pebbles the layers are of different colours. From this structure it is plain they have been formed by successive incrustations of flinty matter, which has been more or less coloured. Some have the same appearance externally, and are called pebble crystals; they are either colourless, or are all over of the same colour, and from this have derived their names, as carnelion, which is of a flesh colour. In others, the colouring matter is disposed in a fantastical or irregular manner, as in the mocao stone. Some have transverse plates, as the onyx.

Another kind of strata, which is chiefly composed of flinty matter, is that of porphyry, in which the flinty matter has such an admixture as to be quite opaque; but in general the principal parts are variegated in different colours.

There are several other kinds of rocky strata, which, though not entirely composed of flint; have yet a considerable quantity of it; as the granite and common whin, which only differs from the former in containing a quantity of iron: it is sometimes called touchstone, or *lapis medius*.

The granite is composed of quartz and sand, differing considerably in colour according to the admixture, but is always composed of hard flinty grains cohering together. This was formerly famous in Egypt; some of the monuments, which were afterwards transported to Rome, were made of it. These are all varieties of the same stone, which is become the object of more general attention since its use in the manufacture of porcelain.

The common whin is well known; but a particular kind, basaltes, is remarkable for being crystallized in large columns, such as the Giant's Causeway, where the pillars are nearly of a regular figure, plainly resembling each other in size, and in the number of their sides, most of them hexagonal, and in close contact with each other. This particular arrangement seems to depend on the slow concretion of this sort of matter, which has been softer, and, in consequence of its moisture being evaporated, has hardened and split, as we see clay or dry sand after wet weather. What first led to this opinion was an observation made upon the form into which other bodies split in the same circumstances; as starch, for instance.

Pudding-stone and some kinds of free-stone may be referred to this class.

Pudding-stone consists of gravel, sand, and stones cemented together, and has its name from its appearance.

Upon the whole, we find this stony matter in a great variety of strata; it is also found in the veins of rocks in the form of quartz. This is a flinty matter, which, when pure, is almost transparent, strikes fire with steel, but is more brittle and shivery than any of the other substances of this kind. When it is very white, or has a milky opacity, it still strikes fire with steel, but is not so hard as common flint. This whiteness and softness seem to depend on the admixture of a gypseous spar; it is therefore called the sparry quartz. The *black* or *gun* flint is accidentally found in the strata of other matter, always in those of chalk or limestone: it is found in irregular figures mostly lying in horizontal beds, at no great distance from each other.

Jasper is another appearance of this earth, in the form of separate concretions. Chemists distinguish it by its colour. The best is of a beautiful deep green, and, when viewed through the light, is variegated with reddish or purplish spots.

To this head may be referred that beautiful blue stone *lapis lazuli*, which owes its colour to iron, as Margraff demonstrated.

Crystals are always found in the cavities of veins, and in the strata of flinty matter, when these are not filled up with quartz. Some are quite transparent, others white, others of a dark or smoaky colour, which they lose in the fire; but they are very liable to be cracked during the operation. Some of these crystals are more regularly formed than salts, and are hexagonal. Some are small and opaque, and have a pyramid at both extremes. They are called rock crystal, from the situation in which they are often found.

Gems are found in the state of crystals, or of pebbles; the last are most valued, and are found in the strata of gravel, from which they are distinguished by their lustre.

The gems are distinguished by a greater lustre, and resistance to fire, and hardness; but most of them seem to have the same earth for their basis as the rest, viz. silica. The diamond consists, however, of pure carbon; and the sapphire is chiefly alumina.

Lastly, we find the flinty matter in petrifactions, as of wood, teeth, and calcareous earth.

The first effect of heat on flinty substances is taking away their transparency, and rendering them brittle. Some are liable to be intersected with innumerable flaws. The hardest kinds resist the fire the most. The alkalies act very forcibly upon silica, and the best known and the most useful property of this earth is, that of melting with a moderate quantity of fixed alkali into a glass. Flints and alkaline salts are the most indispensable ingredients in glass; but sometimes other substances are employed to improve the colour.

Silica will not combine with any of the acids, except the fluoric, the phosphoric, and the boracic, but the action of the first of these upon flints is alone worth remarking. In this acid silica dissolves with the greatest facility; and what is most extraordinary, it is retained by the acid even in the form of gas, so that the silica rises with it even into the atmosphere. If the gas is, however, brought into contact with water, the silica is immediately precipitated in the form of a white crust. It is evidently by its attraction for silica that the fluoric acid dissolves glass, as described in a former lecture, for common glass is formed of silica and carbonat of potass.

IV. Magnesia has not been long known to

chemists. About the beginning of the last century a Roman canon exposed to sale a white powder, as a cure for all diseases, which he called magnesia alba. It was at first suspected to be a composition of lime, but was afterwards discovered to be a peculiar kind of earth.

Magnesia has never yet been found native. It may be procured from sulphat of magnesia, a salt which exists copiously in sea water, and in some springs in the neighbourhood of Epsom, whence it formerly obtained the name of Epsom salt. The sulphat of magnesia used in medicine is chiefly obtained from the mother ley of common salt, that is, the liquor which remains after the muriat of soda has been crystallized and extracted. To obtain the earth in question, the sulphat of magnesia is dissolved in water, and half its weight of potass added. The potass having therefore a stronger affinity for the sulphuric acid, the magnesia is precipitated, and is afterwards washed in a quantity of water to extract whatever salt may remain, and dried.

Magnesia is, I believe, only used in medicine to remove acidities from the stomach and bowels. In this case the carbonat of magnesia is preferable to the pure, for all absorbent earths are rendered somewhat caustic by being deprived of the carbonic acid.

It combines artificially with few substances, but is found in nature united with silica and alumina in a class of stony bodies, which Mr.

Kirwan has classed together; these are talcs, asbestos, &c.

TALCS may be defined earthy or stony bodies, so soft as to be cut with a knife, which do not effervesce with acids, and suffer little or no change in the fire. They are distinguished from flints by their softness; from lime, by not effervescing; from gypsums, by not calcining into plaster; and from clays, by not having the same qualities with respect to water. The appearance of talc is that of a foliated stone, slippery and unctuous to the touch. It splits easily into plates, which differ from the gypseous in being flexible and elastic. These plates, when of the purest kind, are transparent like glass, but many are tinged with a variety of colours, and are more or less opaque. Sometimes they have a lustre resembling that of metallic substances, &c. Sometimes talcs are in the form of shining powder, like that which is used in bronzing figures. The appearance has often imposed upon miners, who have thought they met with gold and silver, whereas there is never any metal in these substances but iron.

They are found also with other stones, as the granite, which frequently contains a great quantity of talc. Free-stone also contains more or less. Its horizontal layers have between them a thin stratum of talc, which makes the stone more easily separable. Talc is also found in some kinds of slate, which, when long exposed to the air, moulder into talcky powder. The common talc is used in making lanterns used in the powder-rooms of ships, as they do not take fire or crack with heat.

The asbestos, or amianthus, is a fossil agreeing with talc, in having a regular structure, in being flexible, but differing in being composed of fibres instead of plates. When long exposed to air, it dissolves into a sort of stony matter, which has some degree of toughness, but the fibres of which cannot be unravelled. Cloth and paper have been made of this substance, which resist the fire.

Steatites, a kind of magnesian earth, is an ingredient in porcelain, the art of making which was long confined to China; but of late all the necessary discoveries have been made in Europe. A Jesuit missionary first sent an account of the manufacture to France, and specimens of the two ingredients, viz. *kaolin* (a white clayey earth), and a stone called *petuntze*. Reaumur examined and gives the following account:—One of the substances is not fusible, the other is by a strong heat. He supposed that by union they underwent an approach towards fusion; this gives the semi-transparency to china. Meeting with no substances of equal purity with these, he made experiments on common glass and talc, by which he produced a substance white like porcelain, and which resisted heat and cold.

The qualities by which the best china is distinguished from the worst are, that it has a beautiful semi-transparency, and upon breaking shows a sort of vitrification, yet withstands violent heat, &c.; whereas the false china melts in a heat very intense into an imperfect kind of glass, and is very apt to break on pouring hot water into it, especially if it stands upon a cold substance. This has for its basis the clayey earth mixed with a proportion of glass. The Saxon manufacture has subsisted longest in Europe, and is most famous, its productions equalling the best foreign china.

In England many persons used the soap rock (whose principal ingredient is magnesia); but Mr. Cookworthy, of Plymouth, found out that the true materials of china are in great abundance in Cornwall. The kaolin being a clay of uncommon whiteness and lustre, contains a very great quantity of a very fine talc. The petuntze is a stone of the granite kind*, which contains a great quantity of the fusible stone; this must be powdered for use. The kaolin, when melted, alone produces the stone china, or Japan porcelain, which is less transparent, and harder than the ordinary kind.

V. Barytes is the heaviest of all the earths, yttria, and perhaps zirconia, excepted. It is obtained from a mineral not uncommon in

---

* The common granite contains iron, which would discolour the china.

England, called *ponderous spar*, which is a sulphat of barytes. By reducing the mineral to powder, and keeping it for some hours red-hot in a crucible, with an eighth part of its weight of charcoal in powder, it is converted into a sulphuret of barytes. The nature of this process you will easily comprehend. The oxygen of the sulphuric acid combines with the charcoal, and goes off in carbonic acid gas, leaving the sulphur behind with the barytes. The compound is dissolved in water, and nitric acid being poured upon it the sulphur is precipitated. The nitric acid is afterwards driven off by heat, and pure barytes remains.

Barytes does not combine with oxygen, azote, the alkalies, or metals; but it unites and forms compounds with sulphur, phosphorus, and the mineral acids. It is used, though sparingly, in medicine, and some of its compounds as tests in chemistry.

VI. STRONTIAN is an earth lately discovered, and takes its name from the strontian lead-mine in Argyleshire, where it was first found. It is always found combined with the carbonic or sulphuric acid. It is of a greyish-white colour; its taste acrid and alkaline; it converts vegetable blues to green, and has the singular property of tingeing flame of a beautiful red, or rather purple colour. It has not as yet been applied to any use in the arts.

VII. YTTRIA is also an earth lately discovered in Sweden. It is only found combined with the black oxide of iron. It has, when extracted from the mineral in which it is found, the appearance of a fine white powder destitute of taste and smell. It is much heavier than any of the earths, its specific gravity being 4·842.

VIII. GLUCINA was discovered in 1798, as a constituent of those beautiful gems the beryl and the emerald, from which it is obtained by fusing them with potass, dissolving the mixture in muriatic acid, and separating the ingredients. No remarkable properties have hitherto been discovered in this earth.

IX. ZIRCONIA has been lately found as constituting a part of a precious stone found in the island of Ceylon, called *jargon*, or *zircon*, and also in the hyacinth, another gem from the same island. It is heavy, and fuses into a very hard grey mass, resembling porcelain.

LECTURE XXXI.

CHEMISTRY.

COMBUSTIBLE SUBSTANCES.

COMBUSTIBLES are substances capable of combustion, which process has been explained in a preceding lecture. Yet it may not be quite useless to repeat, that the cause of combustion is, in truth, a chemical attraction; and combustibles are those substances which have a strong attraction for oxygen. You will remember, therefore, that about one-third of the air of our atmosphere is oxygen gas, or air, which contains an immense quantity of caloric, elementary fire, or heat in a latent state, to keep it in the aërial form. This part of the air is always destroyed by the process of combustion, as is proved by letting a candle burn under a receiver till it goes out. The true explanation of the phænomenon is, then, that the combustible body, being in part decomposed by the action of heat, unites with the oxygen of the air, and together they form a third substance, (as hydrogen or inflammable gas and oxygen form water*,) and by this condensation of the oxygen, a large quantity of caloric escapes, and becomes sensible, so as to produce heat, and frequently flame.

---

* If a receiver, properly cooled, is placed over one of Argand's lamps, a large quantity of water will be found in it.

As the contact and succession of fresh air is necessary to the combustion of bodies, we find that it takes place always on the surface. Thus a piece of charcoal is only consumed on the surface; for if we break it, we find it still the same in the middle. Thus, spirit of wine burns at its external surface, for a cotton wick remains without change.

Of combustibles, some burn without, and some with flame.

The first are, charcoal of various kinds, metallic bodies, if they may be classed as such, &c. The second are very numerous, as sulphur, oils, spirit of wine, &c. The proper distinction between these classes is, that the one is fixed, and the other volatile. In the fixed body, the consumption can only happen on the surface, while those that are volatile are converted into vapour in a heat below that necessary for their inflammation; and consequently the vapour only can be heated to a proper degree and set on fire. Flame is only a succession of burning vapour, therefore it is always in some degree conical; for it is consumed as it ascends, therefore diminishes from a broad basis, and terminates in a point. This form is most observable in the flame of spirit of wine. The vapour, as it rises, is not wholly consumed; the reason is, the air has not free access to the centre of the column of vapour. The combustion, therefore, takes place where the air has freest access, viz. on the surface. If a ball of sulphur is suddenly plunged into the flame, it will appear that a considerable part of the vapour is not on fire. The flame is a hollow cone, surrounding an entire cone of vapour.

Flame vibrates, because the vapour is thrown out irregularly from the body, and because, being an elastic fluid, the smallest disturbance in the air makes the two springs, *i. e.* of the air and of the vapour, act on each other, and produce expansion and contraction.

Soot is a part of the burning vapour which has not been so much inflamed as the rest. In large flames, the surface on which the air acts is less in proportion to the quantity of vapour than in small flames; hence, proportionally, more smoke and soot is formed from large than small flames.

Combustibles are judiciously divided into simple and compound. I. The simple are *hydrogen*, *phosphorus*, *sulphur*, and *carbon*. Dr. Thomson observes that the metals might be included, but the greater number of their properties are so different from the four bodies just mentioned, that it is more proper to consider them as a distinct class of bodies. This judicious philosopher adds:—"All our classifications are in fact artificial; Nature does not know them, and will not submit to them. They are useful, however, as they enable us to learn a science sooner, and to remember it better: but if we mean to derive these advantages from them, we must renounce a rigid adherence to arbitrary definitions which Nature disclaims."

1st. Of HYDROGEN it was necessary to treat so amply as a simple substance, that scarcely any thing remains to be said of its combustible qualities. If hydrogen gas is mixed in a receiver with oxygen gas, in the proportion of fifteen parts of the former to seventy-five of the latter, and an electric spark is made to pass through them by means of a wire inserted in the receiver, they will explode, and pure water will be formed. This experiment is generally made in a tub of mercury, with the pneumatic apparatus, as described in Lect. 25. See Pl. VI. fig. 19.

Philosophical fire-works are also made by means of different mixtures of this gas with other aërial fluids. Bladders, with glass tubes and brass cocks affixed to their necks, are filled with the different modifications of this gas; and when the cocks are turned, the inflammable gas issues out, and may be inflamed by a candle. Pure hydrogen gas affords a white flame; with a mixture of atmospheric air the flame is blue; and when mixed with carbonic acid gas in different proportions, the different shades from red to purple are produced.

2d. The appearance of PHOSPHORUS has already been described to be that of a transparent substance, of a colour inclining to yellow, like a clear horn; it is specifically heavier than water, is tough, and cuts like bees-wax, and, like it, melts in a gentle heat (99°) into a transparent fluid, and indeed with a less heat. With this heat it may be melted in water; but if the same or even a lower degree of heat, (43° for instance,) is applied in the open air, it melts, takes fire, and burns, producing a bright white flame with intense heat*. Those who have been accidentally burnt with it complain that it gives more pain than any burn whatever. This is partly from the intenseness of the heat, and partly from the nature of the matter produced during inflammation; the phosphorus being converted into an acid.

The very small degree of heat necessary for setting it on fire, shows the very strong attraction it has for the oxygenated part of the atmosphere.

When the process of inflammation is going on, the phosphorus is gradually changing its nature. The oxygen is attracted from the atmosphere, and becomes united with it, converting it into an acid matter, then called phosphoric acid.

The following is Dr. Thomson's process of preparing phosphorus:—Let a quantity of bones be burned, or, in the chemical language, calcined, till they cease to smoke or to give out any odour, and let them afterwards be reduced to a fine powder. Put one hundred parts of this powder into a stoneware bason, and add gradually (stirring the mixture) forty parts of sulphuric acid. Leave the mixture for twenty-four hours, stirring it occasionally. Strain the liquid into a porcelain bason through a filter of cloth; the white powder which remains may be thrown away. After this, pour slowly into the liquid acetat of lead dissolved in water, when a white powder will be precipitated. This white powder, after being washed, is to be mixed with one-sixth of its weight of charcoal powder. It is then put into a retort, which is placed in a sand bath, and the beak of it plunged in a vessel of water, and after some time the phosphorus will come over, and congeal under the water. I have phosphorus now in my possession twenty years old, which retains all its properties. It has of course been kept in water.

---

* A trick is played with this phosphorus, viz. setting fire to tow wrapped round a bottle, by pouring hot water into the bottle, the outside of which is first rubbed with phosphorus.

Phosphorus combines with sulphur in different proportions.—When the phosphorus exceeds, it is called phosphuret of sulphur; when the sulphur predominates, sulphuret of phosphorus. When used internally it is a poison.

The combinations of the phosphoric acid with different substances, or *phosphats*, are very numerous. Phosphat of lime is the basis of all bones, whether human or of other animals, and this is the reason of the above process, which extracts the phosphorus from calcined bones. The sulphuric acid expels the phosphoric from the powder of the bones, and seizes on the lime. The sulphat of lime is the powder which is thrown away. The phosphoric acid remains behind, and when heated with charcoal in a retort, the oxygen comes away with the carbon in the form of carbonic acid gas. The pure phosphorus, therefore, comes off into the water in the receiver.

3d. **Sulphur** comes properly after phosphorus, as it equals it in simplicity, and is changed in the same manner. Sulphur or brimstone is, in fact, an elementary substance, which has, like phosphorus, a strong attraction for the oxygen of the air. When inflamed, therefore, the oxygen is drawn from the atmosphere, and, uniting with the sulphur, the heat or fire which the air contained is let loose, and the sulphur, by this process (like the phosphorus) is changed. It assumes the acid character, and becomes sulphuric acid. When the sulphur is imperfectly oxygenated, it is volatile, in the form of sulphureous gas, or sulphurous acid. Sulphur unites with the fixed alkalies, and forms sulphurets, or livers of sulphur.

The attraction of sulphur for lime is so weak as to be overcome by the weakest acid. A similar production to the livers of sulphur may be obtained by the volatile alkali, but by a different process.

Mix three parts of sal ammoniac, three of fresh quick-lime, two of flowers of sulphur; distil them with a gradual heat: when the heat rises to a certain degree, the alkali is in a caustic state, combines with the sulphur, and forms a sulphuret much stronger and more penetrating than that formed by fixed alkali. It is called sulphuret of ammonia, or volatile tincture of sulphur, and is administered by some quacks to expel the gout, but very absurdly. This volatile sulphuret emits fumes, and has a disagreeable smell, like all other solutions of sulphur.

Sulphur is often found in considerable quantities in a pure separate state, especially in the neighbourhood of volcanos, or in countries where they have existed. It is contained also in small quantities in the waters of some mineral springs, as those of Harrowgate, for instance. The waters that have a sulphureous smell do not indeed all contain actual brimstone, but a volatile vapour, producing the same effect as the vapour from a solution of sulphur.

Sulphur combines with all the other simple combustibles and metals, forming sulphurets; and with some of them in a superabundant dose, forming super-sulphurets. One of these latter is particularly deserving our attention.

Pyrites, which is a super-sulphuret of iron, is a mineral of considerable weight, in appearance and colour resembling brass. It is of various forms. Those pieces that are cubical prove that this matter is disposed to crystallize. Most commonly it is met with in masses which have no regular external form. Those which are round have a fibrous structure, radiated from the centre to the circumference. Those used for the manufacture of brimstone are so hard as to strike fire with steel. We discover the composition of pyrites by heat: it burns like brimstone; and if a stronger heat is applied, it rises in vapour, which when condensed is brimstone.

The sulphur thus obtained is, however, seldom pure, the steam of metals, earths, and other substances condensing along with it. It may be purified by being melted in an iron vessel, and kept in a melted state, and then the impurities settle at the bottom, and the matter being skimmed, is cast into moulds.

If we wish sulphur still purer, we must use the flowers of brimstone, which is sulphur purified by sublimation; but during this process some of the sulphur is apt to take fire, which gives an acidity to the rest. Hence we find in some flowers a little sulphurous acid, which prevents their gently laxative effects; but this acid may be removed by only pouring boiling water upon the flowers, and drying them again.

Besides the pyrites, there are other substances which contain more or less sulphur; as all ores of metals, except gold. The ores of copper are never without it, also those of lead; but the pyrites is the only ore from which it can be extracted with profit. The combinations of the sulphuric acid have been already noticed under the article salts.

4th. CARBON is the next of the simple combustibles which demands our attention. The principal forms under which this substance appears is the diamond, charcoal of wood, pit-coal, and carbonic acid, wherever it exists. Carbon, however, forms a large proportion of all vegetable matter, and even enters more or less into the substance of most animal bodies.

It is in the diamond alone, however, that carbon exists in a state of purity, and uncombined with other matter. It is not, however, so easy of combustion as charcoal, possibly from its crystallized form, which may not admit of so easy a separation of the parts. Charcoal takes fire at a red heat. The diamond before it can be burned must be exposed to a heat of not less than 5000° in the focus of a powerful burning glass. It is then by its union with oxygen converted wholly into carbonic acid gas. Morveau found that diamond, during its combustion, combines with 4·592 parts of oxygen; consequently carbonic acid gas consists of about eighteen parts of diamond, and about eighty-two of oxygen.

Though we have been successful, however, in dissolving and analysing the diamond, we have not as yet been able to disengage it from the oxygen when united with it, and reduce it again to its beautiful crystallized form; yet it would be rash to say that it never will be done. At least, having advanced so far, we may venture to say, that the making of diamonds would be a much more rational object of pursuit than the philosopher's stone, which so long occupied the attention of mankind.

Charcoal, however purified, is not, like the diamond, a simple substance, for it is always combined with some portion of oxygen, and is therefore an *oxide* of *carbon* or of diamond. Lavoisier ascertained that pure charcoal is composed of about eighty-four parts diamond, or pure carbon, and about thirty-six of oxygen.

It has, however, still a strong attraction for a super dose of oxygen, whence it is very combustible, and by combustion in the open air, or in oxygen gas, is converted into carbonic acid gas. This accounts for its utility in reducing the oxides, or calces, of metals, which, when heated with charcoal, part with their oxygen to it, and carbonic acid gas is formed, and the metals are restored to their metallic state and lustre. Charcoal may be obtained from all vegetable and animal substances, and from fossils of the bituminous kind. It is commonly procured by burning wood with a smothered heat, and extinguishing it when red hot.

Charcoal, unless heated, is in a great measure unchangeable; hence it is common to scorch ends of stakes, &c. which are to be put in the earth, and when thoroughly charred, there is scarcely an end of their duration. Neither moisture, air, nor any thing else affects charcoal as long as it continues cold, nor even heat itself alone, provided the charcoal is kept in close vessels. The explosion of gunpowder greatly depends on the charcoal it contains, which furnishes an essential ingredient of that volume of air which expands upon every explosion.

II. Of the *compound combustibles*, Dr. Thomson most judiciously remarks, that they are almost all combinations of carbon and hydrogen, or of carbon, hydrogen, and oxygen. They comprehend a great part of all vegetable and animal substances.. But from the present imperfect state of chemical science, and still more from the nature of these lectures, which are only elementary, we must confine ourselves to the following: 1, Alcohol, or ardent spirits; 2, Ether; 3, Volatile oils; 4, Fixed oils; 5, Tan.

1st. ALCOHOL, or *ardent spirits*, have the latter name from their inflammability and volatility. The old chemists gave the name of spirit to every subtile penetrating liquor obtained by distillation. It is called ardent, to distinguish it from those that are not inflammable, When most pure, it is called *rectified* spirit of wine, or alcohol. It is obtained by fermentation from vegetable substances, and especially from the saccharine and farinaceous plants which contain sugar, or from a solution in water of the sugar which has been extracted from these vegetables. The same spirit is sometimes produced from seeds, and sometimes from the roots of vegetables, by previously malting and subsequent fermentation: from some it is obtained by dilution and fermentation, without malting.

By fermentation the saccharine and farinaceous matter of vegetables is much changed, so that, though at first rather heavier than water, by the loss of its carbon it becomes at last lighter than water, and discovers some little reluctance to mix with it.

In the various liquors thus produced there is always alcohol, water, tartar, a mucilaginous matter, and a peculiar oil to which they owe their flavour; the quantity of alcohol is small in proportion. The strongest wines do not contain above one-eighth; those that are esteemed very strong, not more than one-twelfth; and small liquors much less.

To separate the spirit pure is a difficult process. The fermented liquor is first distilled. As the spirit is the most volatile, it rises first, but not without a quantity of water; and though a great deal of the water, acid, and mucilaginous matter is separated, not only water, but the volatile oil has arisen, of a different flavour according to the liquor employed and the management of the fermentation. The more complete the fermentation, the less there is of the oil.

To this oily matter the ardent spirits owe their different flavours, for when it is separated they have all the same flavour. It is best distinguished when the spirit is diluted with water, which renders it milky. The water having a stronger attraction for the spirit than the oil, the oil is in some degree precipitated, and the flavour rendered more sensible. A strong spirit scarcely parts with its oil but in this manner.

It is generally found that a second process or distillation is necessary, which is called *rectification*; thus the spirit is freed from the water and the subtile oils, though it is not always easy to separate them. If, however, the vinous liquor is such as yields a spirit of the purer kind, the second distillation will be sufficient. In this case it is recommended to add a little water. This may seem whimsical, as one end of the distillation is to separate the water; but the use of it is to get rid of the oil. Water is particularly necessary in the rectification of small spirits, when intended for the nicer purposes of pharmacy or compound waters, which ought to have no bad flavour.

When the quantity of liquor is great, it is easy to obtain some spirit exceedingly strong, provided the heat at first is slow; but in small quantities of liquor the spirit can only be obtained pure by means of an elective attraction.

An ordinary fixed alkali, as pearl ashes, is added to it, which attracts the water, is dissolved, and sinks with the water to the bottom; after this pour off the spirit, and add more alkali, which will not be dissolved, but moistened; repeat the operation till you observe the alkali perfectly dry, when you may conclude that all the water is separated. By these repeated *decantations* we may render the spirit sufficiently strong; but the alkaline salt acting on the oily matter, imparts to the spirit a yellow colour, and part of the alkali being dissolved with it, gives the spirit a disagreeable taste. In order to separate this and the oil which still remains, it is necessary to distil the spirit in a more gentle heat; and some, thinking that the alkali may still rise, advise a quantity of burnt alum to be added, that it may convert the alkali into a sulphat of potass; but without this addition, if the heat is gentle, we obtain the spirit free of the alkali, which, when quite pure and transparent, is called ALCOHOL.

The stronger any spirit is, the lighter it is. In judging of spirits, dealers trust to proof by the bell, as it is called. For if brandy, containing equal parts of spirit and water, is shaken violently, bubbles are found of a particular size, which remain for a certain length of time, and arrange themselves round the sides of the phial. The particular size is known by experience, but the appearance is different if the spirit is either weaker or stronger than proof. This method, however, cannot be depended upon, as the bubbles of a weaker spirit more oily than ordinary, have the same appearance, and continue as long as those of proof spirit; and some dealers have contrived to give their spirit a certain viscidity which produces this appearance.

Double rum is commonly examined by dropping olive oil into it. If the oil sinks, the spirit is considered as sufficiently strong; if it swims, it is thought too weak. No doubt but the comparing of spirit with other liquors whose density is nearly the same, is the best test of their comparative strength, but it does not determine their particular strength.

In the custom-house they use a ball of metal with a graduated stem*; but they are obliged to vary the instrument for the different spirits, having particular weights to screw on for each; and as the temperature of the air alters much the density of spirit (for spirit has been found to expand seven times as much as quicksilver), they have three or four weights for the different seasons. Yet as these are adapted only to four degrees of heat, as they have no directions on what particular days they must be used, and as what may be called cold in Jamaica may be very warm weather here, this method must be very inaccurate.

Another method is to use a small glass bubble with a graduated stem. The instrument must be nearly of the same specific gravity with the spirit. The lower or higher it swims, the stronger or weaker is the spirit. There are only three or four spirits the precise strength of which it can be of any consequence to know, as brandy, double rum, and the strongest spirit of wine. If we have a small glass ball for each of these, equal in specific gravity to them when of a proper strength, and use at the same time a thermometer, they will answer for all seasons. The painters, who use spirits of great strength, try them by kindling a wick of cotton wetted with the spirit, observing whether the wick is burned. If it is burned, they judge the spirit strong; because if it contained water, it would remain with the wick, and prevent its consumption. But this method is uncertain; for the burning of the wick depends a good deal on the quantity of spirit, and the manner of putting it on.

---

* See the lecture on Hydrostatics.

It is also common to throw some grains of gunpowder into the spirit: if they catch fire, when taken out, it is presumed no water is contained in it, for it would attach itself to the powder, and prevent its explosion.

Alcohol, when pure, consists entirely of carbon, hydrogen, and a quantity of water. By the experiments of Lavoisier, seventy-six grains of alcohol contained about twenty-three of carbon, six of hydrogen, and forty-eight of water. In its strongest state it is a colourless, subtile, penetrating, fragrant, and inflammable fluid. It is one of the most volatile of all bodies, and hardly any thing is so much expanded or contracted by heat and cold. Professor Braun's experiments show it to be the best fluid for measuring intense degrees of cold; but it will not answer for the degree of heat above animal bodies, as its expansion when above this is irregular. It boils in vacuo with a heat less than that of the blood of most animals. On this depends the operation of the pulse-glass, which is a tube with a small bulb at its extremity, containing a quantity of spirit of wine, which, when first put in, is made to boil briskly, that the steam may expel the air; it is then hermetically sealed*, and if the finger or hand is applied, it boils. There is one thing remarkable: if we hold the instrument upright it does not boil easily, but if we incline it ever so little, it boils. The fact is, there seems to be a little air left in the tube, which may be necessary to facilitate the production of vapour; by inclining the tube we let in this air or elastic fluid, and then the spirit boils.

Spirit of wine undergoes spontaneous evaporation in the air, without leaving any thing behind: the vapour burns without smoke, and leaves no excrementitious matter.

The first remarkable effect of mixture on alcohol is its mixing completely with water, which no other inflammable substance will. This proceeds, perhaps, from its being the least inflammable of them. It shows too a considerable attraction for water, for a mixture of them becomes sensibly warm. Their mutual attraction is the cause of their deserting other substances to join each other. Thus, if water is added to a resinous tincture, it precipitates the resin, and mixes with the spirit; and spirit of wine precipitates many salts from water.

---

* That is, by melting the glass at one end of the tube, so as in a manner to solder it together.

The mixture of alcohol with different acids produces some curious phænomena.

The sulphuric acid unites with spirit of wine with great violence. A mixture of this kind is often made on account of the valuable produce by distillation. The process is,

Pour into a vessel capable of bearing a great and sudden change in temperature a quantity of spirit of wine; then pour in an equal weight, not an equal bulk, of strong sulphuric acid, which is almost twice as heavy as the spirit of wine. The acid should be poured in through a funnel, to prevent the effects of sudden mixture. The greater part of the acid, on account of its weight, sinks to the bottom. You may mix them by gentle agitation. The vessel, however, soon becomes too hot to be touched. The mixture must then be distilled with a brisk heat. The present heat of the mixture is such, that if the still has been previously heated, much of the liquor will soon be evaporated. Cold water, or, if opportunity, ice and snow must be frequently applied to the receiver. The first matter that comes over differs little from ordinary ardent spirits, only more free from water. Soon after, a very subtile, volatile, penetrating fluid rises from the mixture, and a grateful aromatic odour spreads through the room: it is called SULPHURIC ETHER. We know when it begins to rise by the striæ formed on the upper part and neck of the retort. When about one-third of the mixture is come over, a viscid matter begins to rise. Here the receiver, containing the ether, must be removed, and another fixed to the retort; for the matter which then rises would render the ether impure. When this process has been carried on too far, a part of the sulphurous acid comes over, which has a disagreeable smell, like that proceeding from sulphur and bitumen. When the acid comes over, it generally gives a moistness to the air.

It is difficult to carry on the process further on account of the black fumes which rise, and which by their expansion burst the vessels. The mixture, when first put into the retort, has little colour; but during the process it changes, first into a yellow, then brown, then black, and becomes viscid. Large bubbles arise, as in tar. In this state it has a very nauseous smell. If curiosity leads us to extend the experiment further, we must proceed with a gentler heat, and thus there arises more of the sulphurous acid and water; at last there remains in the retort a sulphurous carbonaceous matter.

2. **Ether** is the lightest of all fluids, for it floats on spirit of wine, and on every fluid yet known; its weight to that of water being as seven and a half to ten. It is so volatile, that it immediately evaporates, and spreads itself all through the surrounding atmosphere.

As it evaporates very soon in this spontaneous way, so it very soon arrives at its boiling point, which is 100 degrees Fahr. But its boiling point in vacuo appears from some experiments of Dr. Cullen far below frost; wherefore if the pressure of the air did not keep its particles together in all the variations that happen here, ether would never appear in any other form than that of an elastic fluid, like air.

After having shewn that the evaporation of fluids is attended with considerable cold, Dr. Cullen repeated his experiments in vacuo. Among other fluids he tried ether, in a phial surrounded by water. On exhausting the air the ether boiled violently, and the water was converted into ice. Upon the evaporation of the ether, the sensible heat was converted into latent heat, which necessarily produces cold sufficient to freeze water.

Nitrous ether is made by gently distilling spirit of wine with one half its weight of strong nitric acid. The mixture thus distilled has a peculiar fragrance. At first the nitrous ether was only considered as a composition of spirit of wine and nitric acid, till a French chemist obtained ether from a mixture of this kind. He mixed the spirit and acid in the ordinary way, only allowing more acid. He set the mixture by, well corked, and after some time found the ether swimming at the top, with a watery fluid at bottom. This process is disagreeable, on account of the vapours and the danger of bursting the vessel. There are also a muriatic and acetic ether.

3. OILS are combustible substances, formed by nature in animal and vegetable bodies. They may be distinguished into two principal kinds; the volatile and the fixed.

1st. The volatile aromatic or essential oils affect the tongue generally with great pungency and heat, and have all more or less odour, generally strong. They have no smoothness, slipperiness, or unctuosity when felt between the fingers, a quality that belongs to the fixed or *unctuous*, which are particularly bland to the taste and smell; and these two qualities distinguish them, viz. want of taste and of smell. What have been called the *empyreumatic* resemble so much the *aromatic*, that they are only distinguished by their origin, being produced by means of fire.

Volatile oils, as well as the fixed, are composed chiefly of two ingredients, hydrogen and carbon, but they contain a larger proportion of hydrogen than the fixed oils, from which they may easily be distinguished, as when dropped on paper and evaporated they leave no mark or stain behind.—The same test will of course determine whether they have been adulterated with any of the fixed oils. They are very numerous, and differ in fragrance according to the vegetable which has produced them; the most common are oil of turpentine, of lavender, and camomile.

Camphor, according to some chemists, belongs to the class of essential oils, on account of its strong and diffusive smell, being very inflammable, and burning with great obstinacy, even sometimes upon the surface of water. Its flame is very white and bright. It impregnates water with its taste and odour, and dissolves very readily in spirit of wine, from which it may be separated by water. In all these qualities it agrees with the aromatic oils, but differs from them in appearing always in a solid form.

When exposed to heat, it leaves no feculencies behind, and cannot, like the rest, be resolved into an acid water and charcoal. Instead of being liquefied by heat, it totally evaporates before it becomes liquid; for it is one of those bodies which have their evaporating point below that of their fluidity, while under the pressure of the atmosphere; but if close corked up, it melts into a transparent fluid.

To this class may perhaps also be referred balsams and resins, which differ from the oils chiefly in their degree of consistence. Some of the balsams approach in fluidity and tenacity the volatile oils, and on examination shew themselves to be natural compounds of the same materials. Some contain one-half their weight of oil, and the matter left behind is resinous, which may be restored to its former consistence by the restitution of the oil. Many of the aromatic oils, when distilled, leave behind them a resinous substance; and the resins, when first exuded, are almost as thin as aromatic oils.

Balsams and resins are usually obtained by wounding the bark, &c., of the vegetables which contain them, so as to let the juices flow out. These juices at first are fluid, but upon exposure to the air they become thicker by losing some of their water and more volatile parts. In some few cases they are separated by spirit of wine.

2. FIXED OILS are liquid, unctuous to the feel, very combustible, of a mild taste, their boiling point under 600°. They are insoluble in water and alcohol, and leave a greasy stain upon paper. They are obtained partly from animals, and partly from vegetables, and are often called expressed oils, from the manner of preparing or obtaining them. They are produced and contained in particular cells in considerable quantities, so that mechanical pressure is often sufficient for obtaining them. In some cases this is done by heating the vegetable or animal matter, and then exposing it to a strong pressure. It is thus linseed oil is prepared. In other cases the

oily matter is boiled a considerable time in water, as is sometimes practised with olives, and more especially with the animal oils. The water in this case dissolves the matter of which the cells are composed, and sets the oil at liberty.

"It deserves attention," Dr. Thomson remarks, "that the only part of vegetables in which fixed oils are found is the seeds of bicotyledinous plants. In animals they are usually deposited in the liver, though they are found also in the eggs of fowls."—This, however, must be received with some allowance with respect to some animals, since in the most copious quantity they are found in the adipose membrane, as in the lard of hogs, the tallow of cattle, and the blubber of the whale.

Fixed oils are at present considered as composed only of hydrogen and carbon. By the analysis of Lavoisier 100 parts of olive oil consisted of about seventy-nine parts carbon, and twenty-one hydrogen.

Some of these oils have the property of drying easily without losing their transparency, such as linseed oil, nut oil, poppy oil, and hempseed oil. This property is increased by the addition of litharge (an oxide of lead) which is partly reduced by the process, whence it follows that this property is increased by the absorption of oxygen, or by taking away part of the hydrogen.

The mild alkalies, carbonat of potass, soda, &c., have little effect upon these oils; but the caustic, or pure alkali, has a considerable attraction for them, and unites with them into a compound called soap. The caustic alkali gives the soap an attraction for water, and penetrates the oily matter, which we want to wash out. The use of the oil is to soften the acrimony of the alkali, and give it a slipperiness, by which more mechanical force can be employed in washing.

To this class of combustibles we refer all the fossil combustible substances, some of which are fluid, others solid. The fluids differ in degree of fluidity and subtilty. Among the principal of these we reckon naphtha, bitumen, amber, jet, and pit-coal. The grand constituent of all these is carbon, but so infinitely varied, that, though the detail of their properties might be entertaining, it would greatly exceed our limits.

3. *Tan* is, however, a production of a different nature; but its constituent principles have not yet been ascertained. It differs according to the vegetables from which it is produced Nutgalls are supposed to contain the largest proportion. From its propensity to unite with the gelatinous parts of animal matter, and to form with them a hard substance, arises its great use in tanning leather. It is also of extensive use in dyeing, and in the making of ink.

LECTURE XXXII.

CHEMISTRY.

METALS.

METALLIC substances are valuable for their durability in resisting the effects of humidity and of air; for the closeness of their texture, which renders them capable of polish; for the strong cohesion of their particles, which renders them highly proper for utensils where strength is to be combined with moderate bulk.

The first and most obvious property of metals is their remarkable weight, in which they exceed all other bodies. By this they are distinguished from earths, which in some states they resemble: none of the earths, however, are much more than four times their bulk of water in weight; whereas tin, the lightest of metals, is seven times as heavy.

2. They have a great degree of opacity, beating off all the rays of light without receiving any into their substances; and the thinnest film of metal is as perfectly opake as any solid mass. It has been thought that gold leaf, which transmits some rays of light, is an exception; but there is reason to think that this depends not on any pores in the metal, but on cracks and flaws produced by beating: which always reduces me-

tals to a degree of rigidity and brittleness. To remedy this, the metals are generally heated red-hot, and cooled again slowly; in this case their malleability will be increased; and this is called annealing them: but this is not done in beating out gold leaf; it may therefore be very probably broken in several places, and have minute flaws which transmit the light. Krammer says, if the gold is annealed, the leaf will be quite opake.

3. Metals are likewise distinguished by their properties with regard to electricity, which rank them among the most powerful of conductors, and render them more easily affected by lightning than any other matter.

4. Another property of metals is fusion by heat. In this state they always retain their opacity; and there is always a sort of repulsion between them and any vessels into which they can be poured, except metallic ones. Their particles, when melted, have an attraction for one another, in consequence of which they form into spheres. This is evident in quicksilver when thrown upon a table, the globules reflect all the objects round. In general, melted metals have a repulsion for other fluids; hence they cannot be mixed with oils, melted salts, or earths; but some of the combustible bodies unite with them in their melted state.

5. The most common and best known metals possess malleability; and metals are the only bodies in which this property is found.

As to the effects of heat upon metals, they become fluid, like other bodies, in different degrees of it. Many are also volatile when exposed to an intense heat. There is one phænomenon of melted metals, which, to prevent mistake, I will mention; the violent explosion they produce when they touch any thing moist. From what has been previously stated, it is obvious that this effect depends on the great degree of heat the metal is capable of receiving, which converts the moisture into vapour; yet when poured into moulds of sand there is no explosion, though humid, because the vapour easily finds a way through the pores. In general, however, the workmen pierce a number of holes through the sand. Copper and brass produce this effect most, because they receive the greatest quantity of heat when exposed to any given degree. Thus if we expose equal bulks of copper, iron, lead, tin, and silver to the heat of boiling water, and throw them into equal quantities of cold water, the copper will heat the water most, the iron next, and so on in the order recited.

When metals are heated to a very high degree, and the heat continued in the *open air*, they will be reduced to a *calx*, or cinder-like appearance. This is occasioned by their attracting the oxygen from the atmosphere, which then uniting with them, forms them into oxides; and in this state they are soluble in some degree in water. Gold, silver, and platinum are exceptions to this, for their attraction for oxygen is so weak, that they remain unchanged by heat, and have therefore been called perfect metals.

Metals are also calcined, or, more properly, according to the new chemistry, oxidized, by being immersed in the acids, which part with their oxygen to the metals, and reduce them to a calx or oxide. The perfect metals, however, require a peculiar acid to oxidize them, which is called *aqua regia*, and is in fact a super-oxygenated acid. But of this I shall treat more in speaking of the action of acids on them.

The calcination of volatile metals, such as zinc, &c. is similar to the burning of combustibles. Their vapour, when it mixes with the air, is oxidized, and has the appearance of white smoke, like that of phosphorus. It attaches itself to the surface of other bodies, and, when collected, proves to be an oxide of the metal. In some cases their dissipation is manifest, as in *zinc*, where the heat and light are evident; but in most others there is no light, though perhaps, if inspected in a very dark room, by a person who had been long in the dark, light might be perceived in many of them.

Copper oxidizes in a heat below that necessary for its fusion; and to prove it, expose pieces of copper to heat and air, and you will find them covered with a dark crust, which may be easily powdered.

Tin is not oxidized till after it is melted: when exposed to an intense heat, the oxidizement is attended with heat and light, or the metal takes fire, and burns like a combustible substance.

Lead also is not oxidized till after fusion, but may be easily reduced to an oxide, by keeping it in a heat greater than that necessary for its fusion; so that a film forms on its surface, which is its oxide. If this film is removed, a new one will form, and thus we may oxidize the whole. But the best and quickest way is to heat the lead to such a degree as is sufficient to melt the oxide, there will then be no film formed on the surface; but the oxide will be melted, and float distinct from the metal, and will then fall to the side of the vessel. This operation is called the scorification of metals. Metals are, however, capable of uniting with different proportions (or in the chemical language, doses) of oxygen. These have been judiciously distinguished by prefixing to the word oxide the first syllable of the Greek numerals*. Thus the protoxide denotes the first oxide, or the metal combined with a minimum of oxygen; deutoxide the second oxide, or the metal combined with two doses of oxygen; and when a metal has combined with as much oxygen as possible, it is denoted by the term *peroxide*.

The rusting of metals is a change to which they are subject in consequence of exposure to the air. We always find the rust to be an oxide, such as that produced by calcination, or by acids; and the reason is plain: a metal rusts by merely attracting the oxygen from the atmosphere, and therefore undergoes a gradual oxidizement.

---

* Thomson's Chemistry.

Metallic oxides are either a powder or a friable substance resembling the earths: they endure violent heat without evaporation. Some of them are fusible, especially when moderately calcined, but always require more heat for fusion than the metals from which they were obtained. They form a mass which has no resemblance to any metal either when melted or congealed. Some of them in this case form glass, like the fused earthy substances. This melted matter or scoria (as of lead litharge) will readily mix with any of the earths in a melted state, and brings many of them into fusion; but it will not mix with metals in their metallic state.

The particular change which metals undergo in consequence of oxidizement, is the means which is commonly recurred to in separating metals from one another. I have observed before, that some oxidize more quickly than others when exposed to the same heat; and as no oxide will mix with a metal in its metallic state, we may separate those which are difficult from those which are more easy to be oxidized. The mixed metal is exposed to a heat sufficient for the oxidizement of the more oxidizable metal; the oxide is kept melted as fast as formed, by additions of saline substances, or other metallic oxides, which promote its fusibility. If the process is long enough continued, the whole of the more oxidizable metal is separated in the form of an oxide, which being incapable of mixing with the more entire metals, remains separate.

Thus gold, silver, and copper, are separated from other metals which are accidentally mixed with them, or contained in their ores; for though all the other metals do not of themselves oxidize, yet by the addition of an oxide of lead they are brought into fusion, and produce scoriæ, which float round the metal. It is true, a part of the metal is sometimes brought into the state of an oxide, particularly copper. But gold and silver suffer no loss in this way, and if the operation is properly conducted, only a small part of the copper is oxidized during the calcination of the more oxidizeable metals; and its oxide is mixed with the scoriæ, and may be afterwards recovered.

Oxides weigh more than the metals from which they are obtained. If we oxidize an hundred weight of metal, its oxide will be greater. Red lead gains ten pounds in the hundred, or more. This is evidently owing to the quantity of oxygen absorbed by the metal, and exactly corresponds with it. Again, by submitting the metallic oxides to a strong heat in contact with any substance which has a stronger attraction for oxygen, as charcoal, or most of the combustibles, the metal will be robbed of the oxygen, and restored to its metallic state. This operation is called the *reduction* of metals. All combustible substances will reduce metals, except sulphur.

The common method is to mix the oxide to be reduced with charcoal, or any combustible substance capable of sustaining a strong heat. Heat is then applied, the violence of which must be different in different cases: the oxide immediately recovers its metallic form, often with the phænomena of ebullition and effervescence.

The metals can also be restored by means of each other. Thus we may reduce oxide of lead by melting it, and throwing in a quantity of iron or steel filings; and the oxide of copper and some others by throwing in a quantity of lead, which is suddenly oxidized, while the copper is reduced, the lead having a stronger attraction for the oxygen than the copper.

The metals themselves will, upon the same principles, recover some of the inflammable substances. Thus phosphorus, after burning, may be reduced by tin, iron, or zinc. Brimstone may be reproduced by silver, lead, tin, copper, &c.

When small quantities of metallic calces are to be reduced, the *black flux*, as it is called, is generally used. It has its name from its colour, which arises from a quantity of charcoal it contains, and from the property of fluxing or bringing metallic oxides or earths easily into fusion. Such a heat should be applied as will loosen the particles of the charcoal from one another, for this will promote the reduction. This method is used in reducing small quantities, as in assaying of ores, but would be too expensive when much is to be reduced. They then mix the oxides or ores with the fuel, and apply a strong heat, but let as little air as possible pass through the fuel; because if air was admitted, it would of course bring a quantity of oxygen with it, which would prevent the reduction. For this purpose, therefore, a particular sort of furnace has been constructed, in which the charcoal of wood is most used; but when metals are much oxidized, we do not find that we can recover the whole of the original metal by this operation, for there is always a portion of it lost.

The metals combine also with the simple combustibles, and the termination *uret* is added to the name of the combustible, to denote the combination.—Thus we have a phosphuret, a sulphuret, a carburet of the metal. Hydrogen does not enter into similar combinations.

Sulphur is the most remarkable among the combustibles for its effects on metals, which show different degrees of attraction for it. Thus, if to a compound of lead and sulphur we add iron, and melt them, the iron unites with the sulphur, and rises upwards with it, whilst the lead is collected into a button at the bottom. A compound of sulphur and fixed alkali proves in general more powerful over the metals than the sulphur or alkali by itself.

Of salts, the acids have the greatest effect in *mixture* upon metals, which have an attraction for acids, and unite with them into compound salts, many of which crystallize. The corrosiveness of the acid is abated by its adhesion to the metal; but not so much as in compounds which contain alkaline salts or earths. There is also a point of saturation: a given quantity of acid converts only a given quantity of the metal into a compound salt; and, on the contrary, the metal attracts only a certain quantity of the acid. But this saturation is not so invariable as that of acids with absorbent earths. In many cases the same quantity of metallic matter may be united with different proportions of acids, and the compound differs in appearance according to the quantity of acid it contains. With a large quantity of acid it is more soluble in water, and is often deliquescent. Where the proportion of acid is small, there is little or no solubility, the metal being only oxidized by taking some of the oxygen from the acid.

Every metal is not disposed to unite with every acid, though some unite with all; others only with one acid. The order also in which they attract them is different from that of alkalies and absorbent earths. Metals attract the muriatic acid most strongly, next the sulphuric, and last the nitric. The metals which dissolve in the same acid differ very considerably in the force with which they attract it, so that they may be employed to precipitate one another. Thus, if we add to the solution of silver in nitric acid, quicksilver, it precipitates the silver; this is again precipitated by copper, and copper by iron or lead, and these by zinc, which may also be precipitated by an alkali.

The solution of metals in the acids is attended with an elastic vapour and effervescence resembling that of acids with alkalies or absorbent earths. This arises from the decomposition of a part of the watery matter of the acid, and the fumes that are emitted are commonly hydrogen gas, which you will remember is one of the constituent parts of water.

The compounds of metals with acids in general are corrosive. There are several combinations of the mineral acids with metals, such as silver, mercury, copper, and antimony, almost as corrosive as the acids themselves; and some even more active, especially when taken into the stomach. Ten or twelve drops of a mineral acid diluted with water may be safely taken; but when combined with some of the metals, such a dose produces the most dangerous effects.

Metals, we have seen, may be separated from the acids by one another; and it is worthy of notice, that when one metal is employed to precipitate another, the metal which is the precipitant dissolves without much effervescence, and this becomes a salt, while the first metal is precipitated in its metallic state. This you will easily understand if you attend to what has been advanced; for the acid with its oxygen is simply transferred from one metal to the other; the latter, therefore, remains dissolved by the liquor, while the former sinks to the bottom.

Alkalies in general precipitate the metals when dissolved in the acids; yet, in many cases, if a greater quantity than is necessary for precipitating the metal is added to the mixture, it re-dissolves the metal. The precipitation made by the alkali is, however, not in the metallic form; and the reason is, that the alkali does not, like a metal, attract the oxygen from the precipitate, which therefore falls to the bottom in an oxidized state. The oxide thus precipitated is always heavier than the metal would have been by oxidizement in the fire. The alkali also dissolves a part of the metallic oxide, especially when pure or caustic, that is, uncombined with carbonic acid, in which state it shews a high degree of activity with regard to the metals, especially if applied to them when melted, dissolving them all, except gold and silver.

The alkaline carbonats, or, as they were formerly called, mild alkalies, have not, however, this last effect: they, and some of the neutral salts only promote their fusion without dissolving them. Borax, for instance, is much used in soldering metals. Its effect in promoting their fusion seems to arise from its forming a continued fluid medium between the sides of the vessels and the surface of the metal; through this medium the heat is transmitted from the one to the other more easily than it would otherwise be. Borax is of use too in promoting the union of the particles of metals, by making their surfaces clean and bright. Globules of mercury, when covered with dust, can scarcely be united; but when made quite bright, they unite as soon as brought into contact. Borax preserves the particles clean by dissolving any particles of dust, or of their own oxides, which may cover them; for borax is a very powerful solvent. By spreading over the internal surface of crucibles, it also gives a small glazing, which makes the vessels pour out better; hence the goldsmiths use it much. The other neutral salts act only by the assistance of heat: by a considerable degree of heat they act upon the metals, and corrode and dissolve them, the acid being loosened by the heat; as sulphat of potass, common salt, &c.

The effects of nitre and muriat of ammonia are much more remarkable. When nitre is mixed with the metals, there is a violent deflagration, attended with intense heat and light, as is the case in mixing it with other combustible bodies, and the metal is oxidized by means of the oxygen contained in the nitre. The alkali of nitre, separated in this manner, proves different from the alkali separated by combustible substances, particularly charcoal; for when they are separated, it is always very mild (because the charcoal supplies it with carbonic acid); on the contrary, when deflagrated with metals, it is always very caustic. The alkali of muriat of ammonia also rises caustic in this case.

Metals do not easily mix with *earths*, glass, or their own oxides; but their oxides readily mix with glass, and give it all the different tinges by which it is made to resemble gems, &c.

Compounds of metals are often more fusible than metals in their separate state; hence they are generally employed as solders, and the compound is of that metal which we desire to unite, mixed with some other, to render it more fusible. Thus the solder of gold is a mixture of gold and silver; of silver, silver and copper; of copper, copper and brass, or brass itself. These compounds oxidize more readily than the metals.

I mentioned the variation of specific gravity as one of the general effects of mixture upon all bodies; but it is very remarkable in metals. Dr. Lewis, in remarking on the compounds of platinum with the different metals, says, he found them sometimes to have more weight than ought to have resulted from the combined weight of the two, as when it was combined with iron. In many cases the compound was lighter, the metal rather swelling than contracting itself.

Few metals are found in a pure state; gold, silver, and sometimes copper, are exceptions. The other metals are generally found in the state of ores, in which they are mixed and blended with other substances, so as not to have the ductility or other qualities of metals: often, indeed, they have the metallic lustre. Sometimes the ore is only a pure oxide, which requires no more than that the oxygen should be drawn from it, by heating it with a combustible substance. Such are all the ferruginous ochres, which are oxides of iron.

The ores of metals are generally found in the veins of mountains or rocky strata, and are always separated from the rocks on each side by a quantity of spar, quartz, or sometimes soft clay or earth. The spar is generally of the gypseous kind. These form the *matrix* of the ore; in England called the rider. In different veins it is of different thicknesses; the quantity of the ore increasing as that of the matter which surrounds it diminishes. Often the ore is in branching masses, wandering irregularly through it, and is often rudely mixed with the matrix in veins of different thicknesses. These are called brangled ores.

The veins or fissures of the rocky strata are sometimes only a few inches wide, and sometimes many yards. In rich mines there are immense masses of ore many feet broad. Where the veins happen not to be filled up, we find the ores crystallized round the cavity.

The ore, when separated from the matrix, generally contains some other matter; as sulphur, arsenic, or both, and sometimes an earthy substance, the whole being united into a compound which at first appears homogeneous.

The first operation on metals is to separate the ore from the matrix. When the ore is found in large masses, most of it may be dug up free from the matrix, and those pieces to which it adheres may be freed by a hammer. But as the ore is often intimately mixed with the matrix, it is necessary to try other methods.

Sometimes the whole is reduced to powder, and thrown into water; the water is then put in motion, and the earthy matter floats above the ore, on account of their different specific gravity. It is still better to place the powder on a board, over which water may be made to run; being stirred while the water runs over it, the earthy parts float, and are carried off, whilst the metallic parts remain behind. This operation is called *washing* the ore.

When the matrix is not divisible by water, a stamping-mill is employed, which consists of an axis turned by a water-wheel. On the axis there are a number of cogs, which lift up a perpendicular pillar of wood, plated at bottom with iron; this, falling down, bruises the matrix to powder. It often happens that the matrix is harder than the ore, and in this case the ore will be reduced to a much finer powder than it. Though the ore is a much heavier substance; yet its surface may be so much increased, that it may be carried off by the water before the matrix. This may be obviated by subjecting the mass to a brisk heat, and throwing water upon it when red-hot, which renders the matrix more easy to be powdered. There are many ores of this kind which undergo a fusion by heat; hence the small particles of the matrix which are angular and irregular, contract themselves into little spheres, by which means, losing part of their surface, they become specifically heavier, and fall more readily to the bottom of the water: the ore too generally loses part of the sulphur it contains, and, on this account, becomes specifically heavier: the stone becomes softer, and is sometimes disposed to fall into powder merely by the application of water, especially if composed of calcareous or gypseous spar. Quartz is not indeed so easily heated in this way, but it becomes softer by these means; cracks and flaws are produced in it, and of consequence it is more easily divided.

After all, there will in washing be some loss of the metal: hence it is found more expedient to bring the whole mass into fusion, as is much practised in Germany. The fusion is performed in some of the ordinary furnaces, and commonly with the addition of particular stones, or the scoriæ of former fusions, which greatly promote the fusion of the new matter. Thus, the metallic matter settles to the bottom still in the state of an ore, whence the process is called *crude separation*, when the ore is thus freed from its matrix. The next operations are to separate the sulphur, arsenic, &c., which the metals may contain; and this must be done by a mild heat, because of their strong adhesion to the metals, which the metallurgists call their *rapacity*. If exposed to a violent heat, the arsenic will hardly separate when forced off intensely; sometimes carrying off part of the metal along with it. This treating the ore in a gentle heat is called *roasting* it. The workmen commonly build the ore into heaps with fuel, so that the whole may become red-hot, and the air have free passage through it. Some ores, as those of copper, require many repetitions of the process, the sulphur and arsenic adhering so closely.

In consequence of this operation, the metal remains more or less in the form of an oxide; the operation of *reduction* becomes therefore necessary. It is often proper to add earths to the ores, as they frequently contain earths not so easily fusible, but which, by mixture with others, become so. The fire being kept up for some time, the ore melts, and as it passes through the fuel, which is generally charcoal of wood, the oxygen which the calx contained is drawn off by the charcoal, forming carbonic acid gas, and the metal falls into the bason constructed for that purpose in the furnace.

Thus the metal is obtained free from earthy and stony matter, and generally from arsenic and sulphur, but it sometimes contains other metals; thus copper has always with it more or less of iron, silver, a quantity of copper, &c.

Some, as lead ores when rich, are treated by immediate fusion, without previous roasting; for though it would give a greater quantity of the metal, it would be too expensive. There are many ores in which the metal exists in the state of an oxide. Here previous roasting would be of no advantage. The ores of silver and gold require certain additions to them, to attract the sulphur and arsenic, and to melt the other matter which is mixed with them, so as to dispose them to separate.

To this account of ores must be added some observations on assaying. It seldom happens that the same person takes the ore out of the mine and refines it. But to know the value of it, they must know the quantity of the metal which the ore contains.

The *assayer* takes a small specimen, about one-eighth of an ounce. He first, if there is occasion, performs the operation of washing, then separates the sulphur and arsenic by roasting, &c., observing with attention what matters are evaporating: he then melts the ore in a crucible with other substances (to promote the fusion and attract the oxygen), of which black flux is the chief, with a quantity of common salt. Sometimes glass or borax are used to bring the metal into fusion, and preserve it from scorification; and sometimes pure alkali and charcoal dust are preferable to black flux, as in the case of iron. When a proper heat is applied, the metal appears at the bottom, and by corresponding weights he calculates how much a hundred pounds of the ore will produce. The operation is nice, and therefore generally requires to be repeated; as a slight variation in the heat employed to reduce the ore, will either fail to give it the necessary fluidity, or too great heat may oxidize some of the metal.

Metals were formerly divided into—1st, The perfect, or such as could not be calcined or oxidized by the application of heat; and these were gold, silver, and platinum: 2d, Imperfect or base, which might be calcined, but which were malleable; such were mercury, copper, iron, lead, and tin: and 3d, Semi-metals, which were not malleable; as antimony, &c.

Dr. Thomson adopts a division more agreeable to the principles of modern philosophy, and reduces them under the following heads.

I. Malleable.

1. Gold.
2. Platinum.
3. Silver.
4. Mercury.
5. Copper.
6. Iron.
7. Tin.
8. Lead.
9. Nickel.
10. Zinc.

II. Brittle, and easily fused.

1. Bismuth.
2. Antimony.
3. Tellurium.
4. Arsenic.

III. Brittle, and difficultly fused.

1. Cobalt.
2. Manganese.
3. Tungsten.
4. Molybdenum.
5. Uranium.
6. Titanium.
7. Chromium.
8. Columbium.
9. Tantalium.

Of the twenty-three metals at present known, only eleven had been discovered before the year 1730. Those of the first class are the most useful, and most generally known. Antimony and arsenic are chiefly remarkable for the use of their oxides and compounds in medicine; cobalt and manganese are useful in the manufactures of china and glass. Bismuth, dissolved in an acid, and precipitated in the form of an oxide, produces that pernicious cosmetic called pearl white. The new metals have not been found, as yet, of any use whatever, and are only objects of curiosity to the mineralogist.

I shall conclude this lecture with a summary view of the most remarkable properties observable in the metallic bodies of the first class, which are by far the most important.

1st. *Gold*, as the most precious of the metals, holds the first rank. It is more ductile and malleable (that is, more easily beaten out with a hammer) than most metals; but it has less of tenacity than some others. It is unalterable in fire, or by exposure to air or water. In philosophical language, it is not oxidizable by these means. From its unchangeable nature and beautiful appearance, as well as its scarcity, it has been adopted as a standard of value for the transfer of of all other commodities.

Gold is, however, not altogether unchangeable; for it may be dissolved by the nitro-muriatic acid (commonly called, on this account, aqua regia), and also by the oxygenated muriatic acid. If a sheet of tin is immersed in a solution of gold, the oxide of gold is precipitated of a purple colour, and when scraped off forms the beautiful purple powder of Cassius much employed in enamelling.

2d. *Platinum* was not known as a distinct metal before the year 1752. Its specific gravity, when pure, exceeds that of gold, and it is therefore the heaviest substance in nature. In ductility and malleability it is far inferior to gold: as it is also the most infusible of metals, it is become of the most material use to chemists, in forming crucibles and other vessels which can endure the strongest heat of a common furnace, as well as the action of all simple acids, without injury. It seems, however, not capable of a high polish, and its dull white colour will probably prevent its use as an ornamental metal.

Platinum unites well with iron; and I have heard that the Spaniards find it of great importance, combined with iron, in the manufacture of musket barrels, which it preserves from rust, (for, like gold, it cannot be oxidized by any ordinary means), and at the same time it gives them additional strength and tenacity.

3d. *Silver*, in beauty, scarcity, and malleability, ranks next to gold. Its uses in the arts and in commerce are well known. In medicine and chemistry it is of considerable importance. Dissolved in nitric acid, it serves the chemist as a test to detect the smallest quantity of muriatic acid contained in any fluid.—For as it forms with this acid an insoluble compound, it will always occasion in any such fluid a visible turbidness, and consequent precipitation. The nitrous solution (nitrat of silver) boiled or evaporated to a solid state, forms *lunar caustic*.

A solution of nitrat of silver stains animal substances of a deep black. Hence it has been applied to alter the colour of red hair. On account of its corrosive quality, however, much caution must be observed in this application, and particular care taken that the solution shall be sufficiently weak.

The nitrat of silver is decomposed by other metals, which precipitate it from the acid. Thus if a little of a solution of the nitrat is applied to a bright plate of copper, it will become plated with silver.

Upon the same principle the beautiful experiment called Diana's tree is made. If into a bottle containing a solution of nitrat of silver a small quantity of mercury is poured, the silver will be precipitated, but as the particles have still an attraction for each other, the precipitation will assume the form of the branches of a tree.

4th. *Mercury* is distinguished from every other metal, by having so strong an attraction for caloric, that it remains fluid in the ordinary temperature of our atmosphere. If our climate was cold enough, it would become solid like the rest of the metals. It has, indeed, been sometimes frozen by natural cold in the very northern regions; but, in general, a powerful freezing mixture is employed to render it solid. The temperature necessary for this effect is seventy-two degrees below the freezing point. In this state mercury appears to be a very malleable and ductile metal, of a lustre nearly allied to that of block tin.

Independently of its uses in the arts, mercury forms the basis of some of our most valuable medicines, such as corrosive sublimate, and calomel, which are muriats of mercury, or mercury combined with muriatic acid.

Of the simple combustibles, mercury only combines with phosphorus and sulphur. The beautiful pigment cinnabar, or vermilion, is mercury combined, by means of heat, with a small quantity of sulphur. Cinnabar is also found native, indeed may be regarded as an ore of mercury, but it is not so pure as the factitious, or that formed by art. They are both obviously sulphurets of mercury.

Mercury dissolves gold, silver, tin, and many of the metals, consequently combines with them. If the other metal is in sufficient quantity, the mercury loses its fluidity, and both united become what is called an *amalgam*, about the consistence of butter. Thus, the silvering of looking-glasses is an amalgam of tin and mercury—a quantity of tin-foil is laid over the glass, and fluid mercury poured upon it. The metals are made to unite by being pressed together by weights. A solid amalgam of lead, and another of bismuth, will become fluid by only being mixed together.

5th. *Copper* seems to have been known the earliest of all the metals, except gold and silver. Utensils and weapons were made of it before the method of working iron was discovered. It takes its name from the island of Cyprus, where it was first wrought. It has a disagreeable smell and taste, and is highly malleable, ductile, and tenacious. In a strong heat it emits fumes, and even burns with a green flame of great brilliancy.

Copper is of essential use in the arts, both in its metallic state, and with respect to the salts which are formed from it, such as verdigrise, which is an acetat of copper, or copper united with acetic acid, and blue vitriol, which is a sulphat of copper.

Copper combines with most of the metals, and its alloys* are important. The gold coin of most countries is alloyed with copper, according to a standard established by law, which is done to render the precious metal harder and more durable. Its alloys with tin will be afterwards noticed. Combined with zinc in the proportion of three parts of copper, by weight, to one of zinc, it forms that beautiful compound brass, which, by the addition of other metals, or by varying the proportions, may be made of various colours, from that of pinchbeck to the lightest coloured brass.

6th. *Iron*, the most useful of metals, is happily the most abundant, and the most friendly to the human constitution. The working of it, unlike that of lead, copper, &c., is perfectly consistent with health. Iron was known before the time of Moses. It has a peculiar taste and smell, and is the toughest of metals, but is less malleable than either gold or silver, or even copper. Its hardness in the state of steel, which is iron combined with carbon, is well known.

---

* Alloys are mixtures of metals; the baser metal, and of which there is least in quantity, is called the alloy. Alloys differ from amalgams in this, that the former are hard, the latter soft. Hence amalgams can only be made with mercury.

The ores of iron are oxides of that metal generally mixed with earth. The metal is separated by fusion with charcoal. In its fluid state it is run into moulds, and is then called pig or cast iron. As this metal, however, has a strong attraction for carbon, it is not so pure after fusion as other metals. Cast iron, indeed, contains a large quantity of carbon, imbibed from the charcoal, with which it is fused, as well as other impurities. To expel these, the pig iron is again heated red-hot, and beaten with immense hammers, wrought by machinery. This process is necessary to render it malleable, and it is thus wrought into bars.

Steel is iron combined with a less portion of carbon than cast iron, about one-sixtieth part of its weight. It may of course be prepared from cast iron, by expelling part of the carbon by heat. It is then called *natural steel*, but is less pure than what is called *steel* of *cementation*. This process consists in laying bars of pure iron between strata of powdered charcoal; and heating them in a close furnace for eight or ten days. This is also called *blistered*, or common steel; what is called *cast steel* contains a still larger proportion of carbon obtained by heating blistered steel with chalk.

Thus iron is capable of combining with different portions of carbon. When the carbon predominates, the compound is carburet of iron, plumbago, or black-lead. When the iron exceeds, the compound is cast iron or steel, in its various states, which may be called subcarburet of iron.

Iron combines with the acids. Sulphat of iron (iron with sulphuric acid) is well known by the dyers, as striking a black dye with infusion of galls, &c.; it is commonly called green vitriol, or copperas. Common ink is made by means of this compound of infusion of galls and copperas, with a small portion of gum to keep the colouring matter suspended.

With the prussic acid iron forms that beautiful compound prussian blue, as stated in a former lecture.

7th. *Tin* is also a metal that has been long known. The Phœnicians procured it from England, and from Spain. It is very malleable, but in ductility and tenacity it is inferior to any of the metals hitherto described.

Its combinations with the combustibles and acids are scarcely deserving of notice. Its combinations with the metals are of more importance. Cannons are made of an alloy of copper and tin; and bronze, bell-metal, and the reflecting mirrors of telescopes are all formed by different proportions of the same metals. Copper vessels are often *tinned*, that is, covered withinside with a thin plate of tin to prevent their oxidizing; all that is necessary is to clean the copper well (for tin will not unite with the oxide of copper) and this is generally done by applying sal ammoniac to the surface. The copper is then heated, and a piece of tin gently rubbed over its surface, which at once assumes a silvery appearance. Tin-plate, the material of tin saucepans, &c., is made by dipping thin plates of iron, well cleansed, into melted tin. The tin in this case not only covers the iron, but penetrates it completely.

8th. *Lead* is almost as generally in use as iron. It is one of the heaviest and most tenacious of metals. It melts easily, and becomes oxidized on its surface by the air. This oxide, when kept stirred in the flame of a furnace, is converted into red lead. Dissolved in vinegar, this metal forms acetat or sugar of lead, a dreadful poison, sometimes, however, used by the dealers in liquors to recover them when sour.

White lead, or cerusse, is formed by exposing plates of lead to the vapours of vinegar, which corrode the surface. The white lead thus formed is scraped off, and afterwards ground and washed, to be used as a paint. This manufacture proves fatal to the workmen in about three years, and ought only to be carried on by condemned criminals.

9th and 10th. Of *Nickel* nothing is to be said deserving your attention. The oxides of *zinc* are used in surgery, particularly in complaints of the eyes, or rather of the eyelids, and in that well known plaster Turner's cerate. When zinc is heated to a strong red heat in an open vessel, it burns with a bright flame, and at the same time emits very light white flakes, which were formerly called *lana philosophica*, or *flowers of zinc*. They are merely an oxide of the metal.

It has been already mentioned that an alloy of zinc with copper forms all the different varieties of brass, pinchbeck, &c.

LECTURE XXXIII.

CHEMISTRY.

WATER, AND MINERAL WATERS.

Some of the antient philosophers supposed that all things were originally derived from water. To form this judgment they must have taken no cursory view of the operations of nature. We see how it produces dews, clouds, rain, snow, and other meteors, and we cannot help observing how every vegetable, every animal, in a manner, seems to rise out of it, and be nourished by it.

Modern philosophy, however, which has introduced us to a new world of wonders, while it lessens those of the antient world, has shewn that water itself, I mean the purest water, is really a compound substance. If into a glass receiver, or other close vessel, reversed in a quantity of quicksilver, we put about three parts of oxygen gas, and one part of hydrogen gas, and cause an electric spark to pass through them (for additional caloric is necessary to promote their union), we shall see the two gasses inflame, the mercury will rise in the receiver, proving that the gasses are condensed, and pure water will be formed. This water may again be decomposed by bringing it in contact with any heated combustible substance, as in making it pass through a gun-barrel heated red-hot, when the oxygen will be abstracted by the combustible or oxidizable matter (the iron), and the hydrogen comes off in the form of hydrogen gas. Water is indeed formed wherever there is a combustion of any matter containing hydrogen, as may be seen by fixing a glass receiver, of a globular form, over one of Argand's lamps, which in a little time will be filled with water. Thus, like most other matters on the surface of the globe, water is continually changing its nature.

While water was considered as a pure elementary substance, some were of opinion that the sea was continually diminishing, so that the parts which are now covered with it would in time be dry land. A number of proofs have been offered in support of this opinion; but those in the Swedish Memoirs, concerning the Baltic Sea, are most curious. We are told that a number of rocks, well known, have, in the memory of many persons now living, become more prominent above the surface of the sea. Solid rocks are the best proof of any opinion of this kind, for land might be washed away, or have additions made to it; but a solid rock, which is composed of materials not so liable to decay, must necessarily show if the surface of the sea is lower.

There were chemical experiments instituted at the same time to account for the supposed gradual diminution of the water of the sea. Van Helmont hinted that water by repeated distillation might be converted wholly into earth. Mr. Boyle repeated the distillation of the same water fifty times in the clearest glass vessels, and obtained at each distillation a quantity of earth. He says, a friend of his obtained at least three-fourths of an ounce of earth from one ounce of water. Boerhaave suggested many doubts and suspicions, and endeavoured to invalidate the credit of these experiments. He says they were not performed with accuracy, that water was entirely a pure substance, but that it was capable of being rendered impure by a variety of mixtures, especially of air, which he says is a chaos; so that if any other bodies were found in water, it was only accidental: hence he supposes, and with justice, that the earth in these experiments proceeded either from dust in the air contained within the distilling vessels, or from some other cause which introduced it previous to the experiments. These experiments, therefore, only serve to show the imperfection of all chemical analysis.

Though water cannot be regarded as a simple elementary substance, yet there are not different sorts of pure water; for water obtained in any manner whatever, either attracted from the air, by deliquescent salts, or from salts themselves, from oils, from animal or vegetable matters, is still the same when rendered pure by chemical means. It is undoubtedly of consequence to consider by what means water may be altered from its purity; but it is not difficult to obtain it in that state in which the most rigid experiment will find no admixture. Distil two-thirds of inodorous, insipid, clear stream, rain, or snow water, in glass vessels, to one-fourth, and the water will be perfectly pure. This operation is always necessary when water is to be used in accurate experiments, for no natural water is perfectly pure. Rain water is, indeed, much of the same purity, when collected in clean vessels at a distance from towns, and answers equally well in experiments with distilled water; it is, in fact, water distilled by nature. Those springs which flow from high and rocky grounds, where we can discover no mineral or metallic substance, are the next in purity to rain water; they are rain water collected on the hills, and filtered through ground, in which there are no soluble materials: but this is seldom the case, for most soils contain lime, &c., but in so small a quantity, that these spring waters are often as useful as the purest. The water of rivers and lakes is never so pure; indeed, it has often a sensible taste and smell.

But, besides the waters of rivers, which usually derive their impurities from a mixture of animal and vegetable substances, there are other waters, even issuing from springs, which have a peculiar taste and smell. When these properties are to such an excess that the waters cannot be applied to domestic purposes, they are distinguished by the name of *mineral* waters.

The substances usually found in these waters are about thirty-eight in number, and may be reduced to the four following heads:—1, Air; 2, Acids; 3, Alkalies; 4, Neutral salts.

I. Atmospheric air is often contained in waters, but its proportion is seldom above one-twenty-eighth part. Oxygen gas is also found in inconsiderable quantities, as well as nitrogen gas.

II. *Acids.*—Of these carbonic acid is the most common ingredient, and gives briskness to the water, like that of a fermenting liquor; this briskness appears most when the water is poured from one vessel into another; it is sometimes, however, so considerable as to burst a corked bottle. This acid, in the form of gas, is sometimes employed to give other wines a resemblance to Champaign. It is extremely volatile, and soon flies off; for, if we expose the water containing it to the air, it loses its briskness: we can promote its separation by shaking the vessel; when the cork frequently flies out with an explosion. An artificial water of this sort may be produced at any time.

2. Sulphurous acid has been observed in several of the hot mineral waters in Italy, in the neighbourhood of volcanoes. Sulphurated hy-

drogen gas is, however, the chief ingredient in those waters which are called sulphureous.

3. The boracic acid has been observed in some lakes in Italy.

III. An *alkaline salt* is sometimes met with in water. This is generally soda. Some experiments of Margraff upon waters of particular wells seem, indeed, to shew that they contain potass, either separate or combined. Some writers mention a volatile alkali in mineral waters. It is true, that whenever a union of nitrogen with hydrogen can be effected, volatile alkali may be produced, but from the volatile nature of the compound the phænomenon must be extremely rare.

IV. *Neutral salts.*

1. The *sulphats* are frequently found in mineral waters, especially sulphat of soda, and still more commonly, sulphat of lime and magnesia. The latter, formerly known by the name of Epsom salt, is almost always an ingredient in those waters which have purgative qualities; in truth, its old name was derived from its being so abundant in the mineral springs near Epsom. Sulphat of ammonia is found in the neighbourhood of volcanoes. Alum is a rare ingredient; sulphat of iron is not very common; and sulphat of copper is only found in waters which issue from copper-mines.

2. Nitre is very uncommon; and, indeed, so

are all the nitrats; that of lime has been found in some springs in Arabia, and that of magnesia in some others.

3. The muriats are more general ingredients. Indeed, hardly a spring has been analysed in which muriat of soda, or common salt, has not been found. Muriat of potass is less common, and so are the muriats of ammonia, barytes, alumina, and manganese. Muriats of lime and magnesia are common ingredients.

4. The carbonats are very general in mineral waters, those of soda, and of lime in particular; the latter is generally held in solution by an excess of acid. Carbonat of magnesia is also very common, and generally accompanied by carbonat of lime. Carbonat of iron is the common ingredient in those waters which are called chalybeate.

In examining any MINERAL WATERS, the first object of attention is to have the water as fresh as possible, as some of the parts are very volatile, and fly off in a short time; a great number of trials are therefore to be made on the spot. We must next notice the soil, situation, and nature of the country in the neighbourhood of these springs, whether it is hilly or flat, whether the hills are rocky, what sort of stone they contain, and whether there are any mineral appearances in the neighbourhood; for it commonly happens that a spring of this kind takes its rise from the bottom of a mineral vein. Another circumstance to be attended to is, the degree of heat of the water, which must be ascertained by a good thermometer. There are many springs that have a temperature of heat a little above the middle temperature of the atmosphere; this should be attended to, though they may not seem to derive any particular qualities from that superiority of heat. The middle temperature of these springs is found to be about forty-eight; they vary, however, in this respect according to their height, as the temperature of hills and mountains is found to differ according to their elevation above the sea. The temperature of these waters in high lands is lower than in the less elevated. The degree of heat in the last is from forty-eight to fifty; of those that are higher it is not so much. It may also be proper to compare the temperature of these mineral springs with that of some common springs in the neighbourhood.

The gaseous matters are separated from water by boiling it in a retort, communicating by a glass tube with a receiver immersed in a tub of mercury. The most common of these is carbonic acid gas. Mr. Cavendish has shewn that water dissolves a quantity of it equal to itself in bulk; but this is soon expelled from it again if the water is agitated. Those who have not a pneumatic apparatus, as it is called, that is, a tub or trough of quicksilver, with tubes and receivers, &c., may determine how much of this gas any water contains by the following method.

Let the water be taken at the spring-head, and put into a quart bottle, over which a bladder is to be tied, or, what is better, the bladder should be placed near the bottle. In the mouth of the bladder one end of a tube must be inserted, and the other end fixed in the cork of the bottle, so as to be even with the bottom of the cork; through this tube the air is to be conveyed, the bottle is then to be immersed in a vessel containing water, which is gradually made to boil, but not so as to boil the mineral water. By this heat the air will be expelled out of the water into the bladder, the bladder is then to be immersed in cold water in a graduated vessel; into this water the air of the bladder must be squeezed. By the degree to which the water rises we may determine the quantity in bulk that the air amounts to. But if we would know whether this air is common air or carbonic, we must repeat the experiment with another bottle, and apply the tube to a caustic alkaline lye; the tube must then have a funnel fixed to its end, that the air may be applied more extensively to the lye, and be sooner absorbed by it; in a short time all the carbonic acid gas will be absorbed, and the caustic lye will leave only the common air. This effect is easily explained on the principles which you have already learned. Every alkali in its pure state is caustic. It is neutralized by the accession of carbonic acid, for which it has a great attraction. The lye is only the alkali dissolved in water. Thus we may learn the proportion of common air and of carbonic acid gas contained in any water whatever.

Carbonic acid, when uncombined in any water, will turn the infusion of litmus red. The redness will gradually disappear, but may be restored by adding more of the mineral water.

Some doubts have been entertained whether the sulphuric acid is ever found in a perfectly separate state in mineral waters, for the waters called acidulated derive their pungency chiefly from carbonic acid. One reason that these waters seldom contain this acid is, that it cannot run far without meeting with some substance with which it will combine. The only manner in which we can imagine the sulphuric acid can be present in mineral waters is, by the decomposition of the pyrites, which melts into a very acid liquor, containing sulphat of iron, with more acid than is necessary for constituting a true sulphat: a part of this will probably be separated and mixed as an unsaturated acid in mineral waters; but still it will be more or less accompanied with iron or alum.

Sulphuric acid exists in waters which form precipitates with the following saline solutions:

Muriat, nitrat, or acetat of barytes,
Do. — — strontian,
Do. — — lime,
Nitrat or acetat of lead.

Of these the most powerful test is muriat of barytes. Acetat of lead is the next powerful. Bergman observes, that paper stained with litmus is reddened when dipped into water containing $\frac{1}{3528}$th part of sulphuric acid.

Sulphur is, however, as I observed, sometimes contained in a volatile or gaseous state. In this it will be sufficiently known by its pungent and suffocating smell, which is like that of burning sulphur. Sulphurated hydrogen gas is the most common form which sulphur assumes in mineral waters. It reddens the tincture of litmus; but the most certain tests are, that it blackens paper dipped in a solution of lead, and precipitates the nitrat of silver black or brown.

Any acid in a fixed state, and in any quantity, if mixed with a mineral water, may be discovered by its sour taste, by the infusion of violets, or by an infusion of litmus. This is the most delicate test; but it has so much sensibility to acids, that it may perhaps be affected by them in a state of combination. This and the syrup of violets may either be used in a liquid form, or by being rubbed on paper and dried. Pieces of paper are indeed the best, as we can compare what is dipped in the water with what is left dry. Alum, however, changes the colour of the infusion of litmus as well as an acid. The infusion is a deep purple; but if alum is added, it immediately turns red. But alum does not change the infusion of violets;

and as no substance retains its acid more loosely than alum, we may conclude that if any water turns the infusion of violets red, it certainly contains an acid of which the most minute quantity tinges the infusion.

Alkaline salts are seldom found in a separate state, but often in a state of combination with the muriatic acid. To discover them in their unsaturated state, we may use the syrup of violets, which is still more delicate with regard to alkalies than acids. A very small quantity of alkali turns it green. If we use the syrup of violets, we must take care that it contains no acidity, which may be prevented by adding minute quantities of alkaline salts as long as the syrup will bear it without changing to a green; but the infusion of dry violets, or paper stained with them, answers best.

The infusion of turmeric, or paper stained with turmeric, is also rendered brown by alkalies, or reddish-brown if the quantity is minute. Paper stained with Brazil wood is rendered blue, but this is also effected by the alkaline and earthy carbonats. When the changes are only temporary, it is generally concluded that the alkali is ammonia.

Mineral waters sometimes contain a fixed, and sometimes a volatile alkali. To determine which of the two any particular water contains, we may add to the water a small quantity of muriat of mercury, which is precipitated by the fixed alkali in a reddish-brown powder, but is precipitated by the volatile alkali in a white powder, the volatile alkali not possessing the power of taking away the whole of the acid from the mercury. The fixed alkali requires some time to precipitate the mercury.

Copper, or the calx of copper, is another criterion of the presence of the volatile alkali, which produces with it a blue solution; but this does not answer if the quantity of alkali is exceedingly small. Verdigris added alone does not tinge water, but falls to the bottom in a subtile powder; yet if the water contains any quantity of volatile alkali, it dissolves the verdigris, and tinges the water a beautiful blue colour.

There are some solutions of lime which contain the muriatic acid, as the liquid shell which is made by adding to oyster-shells one-half their weight of muriat of ammonia, and then exposing them in a crucible to a strong heat. This forms the fixed ammonia, the muriatic acid joining with the lime, but uniting with more than it can retain in solution: therefore, when dissolved, it parts with some quick-lime, which gives the water the properties of lime-water; and it is no wonder if it gives a green to the syrup of violets. No other solution has this effect.

We cannot conceive any earth to be contained in any water in a separate state, unless it is suspended in the form of quick-lime. A nice test of this is the solution of lead in the nitric acid, which, when used for this purpose, must be saturated with as much lead as it can possibly dissolve. On adding this, the water, if it contains lime, is immediately turned muddy. If, upon examining any water, we find by the syrup of violets that it does not contain an alkaline salt in its separate state, and yet find that the lead is precipitated, we have reason to conclude that the precipitation is occasioned in a great measure by lime. It is hardly possible to determine the quantity of this substance; and it is best to trust to the examination of the matter that remains after the evaporation of a large quantity of water.

Bitumen is always discernible in water, by its appearance, smell, and taste. There is also another way of judging of it; it has little or no solubility in water, but floats on its surface: if any part of it is dissolved, it may be separated by evaporation.

Besides these trials, by which several of these substances may be discerned in their separate state, we have many experiments by which we can discover them when combined with other bodies. None of the metals are contained in water in a separate state; but alkalies, earths, and metals are contained in water in a state of combination, chiefly with the sulphuric acid. There are experiments for discovering its existence and quantity, with whatever body it is joined. The solution of lead in the acetic acid is a true test of the sulphuric acid when combined with any substance; the solution, instead of being saturated with the lead, must have a little redundant acid. The reason is plain, for then the lead will not be precipitated by lime or alkalies, for the acid will saturate them, and prevent its precipitation; but at the same time does not hinder the action of the lead if there is a sulphuric acid in the water; for they always unite, and form a compound incapable of solution in water, and which therefore renders the mixture muddy, and afterwards precipitates. All experiments of this kind should be allowed to rest at least twenty-four hours.

The solution of lead in the nitrous acid does not disturb the transparency of pure water; nor will its transparency be disturbed by common salt, or a little of the muriatic acid in its separate state. Ordinary common salt may render the experiment fallacious, as it contains sulphat of magnesia; but if we add the least quantity of sulphuric acid, or any of its compounds, the liquor becomes muddy; when this muddiness appears, we must add a small quantity of the nitric acid, to try if the muddiness will disappear—for an alkali may have precipitated the lead—but then it will be in the form of an oxide, the nitric acid will re-dissolve it, and thus the muddiness disappear. If by this and other trials we have learned that the water does not contain an alkali, and a muddiness takes place, we may be certain that the lead is precipitated by sulphuric acid. A combination of the nitric acid in water cannot be discovered, except by examining the remainder of the water after a gentle evaporation and crystallization. From the experiments of those who have examined waters of this kind, it is always found to be contained in the state of nitre, which may be known by its crystals; but we must never conclude a salt to be nitre, unless it deflagrates with combustible substances. If evaporation shews that the nitric acid is united with an earth, it will be proper to add pure alkali, which will form a nitre that may be separated by crystallization. The alkali used should be potass, as none else can be depended upon. The fixed alkali is said to be often combined with the sulphuric, nitric, and muriatic acids. We know that it is often in a state of combination with the muriatic, and sometimes with the nitric acid; but its combinations with the sulphuric are more doubtful. The experiments which have been supposed to prove the presence of sulphat of soda in mineral waters, have in reality proved the presence of sulphat of magnesia; but the only way of discovering the alkali is by evaporation and crystallization. If, indeed, other experiments shew that this is neither saturated with an earth nor a metal, we must conclude it to be saturated with an alkali; but evaporation is the best method, as it will shew whether the alkali is fixed or volatile; for, by mixing quick-lime with the residuum, it will separate the volatile alkali in a caustic state.

The muriatic acid is easily discoverable by mixture: we have in the nitrat of silver as nice a test of this acid, as we have of the sulphuric in the solution of lead. For this purpose it is necessary that the nitrat of silver should contain a little redundant acid, for if it is quite saturated, it may be precipitated by an alkali or an earth; but if there is a little more nitric acid than is necessary to dissolve the silver, nothing will precipitate it but the muriatic acid, and it is sure to do it in whatever state it is contained in the mineral water. The nitrat of silver has been mentioned as a test of the presence of the sulphuric acid; but I am convinced that it is not affected by a small quantity of this acid, unless it is united with the muriatic; for the sulphuric acid composes with the silver a salt capable of solution in water, whereas the compound with the muriatic acid is totally incapable of solution.

Earths are most commonly combined with the sulphuric acid in a selenitic compound, which in some measure is soluble in water. The proper method of discovering lime, magnesia, or the earth of alum, in water, is the addition of a carbonated alkali, which with the assistance of heat precipitates the earth. Without heat we are not certain of separating the acid, and the mixture must be kept warm for some time, or else the earth will be re-dissolved. If a considerable quantity of earth is obtained by precipitation, it will be easy to learn of what sort it is, by allowing it to settle in a tall vessel, pouring off the water, and then adding to it the sulphuric acid. If it is lime, it will effervesce, and form an insoluble gypsum, or selenitic compound. If it is magnesia, it will effervesce, and unite with the acid into sulphat of magnesia, which we may know by its dissolving in the sulphuric acid, and its bitter taste. If it is alumina, it will effervesce, and unite with the acid into an astringent and sweetish solution, in fact, into alum.

Sulphur must be combined with an alkali or calcareous earth to keep it dissolved in water: when combined with fixed alkali, or quick-lime, it is easily separable by an acid; for the sulphur, being suspended by the alkali, subsides when the acid unites to the alkali. Many sulphureous waters are either muddy at first, or very soon become so.

Metallic substances are very common in mineral waters in a state of combination with acids. Macquer has given an experiment to discover this; he found that the prussiat of potass, or prussian alkali, as it has been called, if saturated with the matter it receives in its operation, has no attraction for acids, and consequently produces no disturbance in a solution of lime and acid; it is only the solutions of metals which are precipitated by it, and it acts upon those, because the metals have a strong attraction for that substance which the Prussian alkali contains; at the same time the acid acts upon the alkali, and produces a double exchange: and thus the metal is precipitated. If iron, it is precipitated in a Prussian blue. If the Prussian alkali is produced by calcination with blood, it will be very difficult to saturate it entirely; and if any part is not saturated, it will precipitate a calcareous earth. The only way of saturating it entirely is by digesting it in Prussian blue already prepared, which tinges it yellow. The metallic substances found in mineral waters are seldom any other than iron or copper, and we may at once discover their precipitates by their colour. When we desire to know more certainly if iron is contained in water, and also the quantity of it, we may use solution of galls, which are the most exquisite test of the minutest quantity of iron. Copper may be discovered by the addition of a volatile alkali, which produces a blue colour, by first precipitating the copper, and then re-dissolving it; though the Prussian alkali answers better. The presence of copper, too, may be discovered by throwing into the water a piece of very bright iron; very soon after (especially if the liquor is warm) the copper is deposited on the surface of the iron; but this seldom happens, unless there is a considerable quantity of copper; which is rarely the case in mineral waters. Zinc is precipitated white by the Prussian alkali; but as the precipitate from many other metals is of the same colour, we must have recourse to evaporation to dryness, and then examine the residuum. If it is zinc, it will convert a small plate of copper into brass. If arsenic is supposed to be contained in mineral waters, we must evaporate them to dryness, and judge by the smell when the residuum is made red-hot, or by trying if it tinges copper white.

LECTURE XXXIV.

CHEMISTRY.

VEGETABLE AND ANIMAL SUBSTANCES.

THE simple substances which enter into the composition of vegetable bodies are very few. As constituent matters, we may confine them to carbon, hydrogen, oxygen, and nitrogen; and the latter exists in very small quantities. In animal bodies the list may be increased, as phosphorus and lime enter in considerable quantities, at least into the composition of the solid parts, as the bones, &c. The alkalies also, and some of the metals, are found in animal and vegetable bodies, but the latter in too small proportions, and too casually dispersed, to allow us to regard them as constituent parts.

From these few simple principles, however, a diversity of compounds are formed. It will conduce much to perspicuity to treat separately of vegetable and animal substances. The physiology of both is foreign to the object of these lectures. Chemistry is concerned with them only when they have ceased to live. It treats of the substances of which they are composed, and of the changes which these substances undergo.

The following are all the substances which have hitherto been found to exist in vegetables.

1. Sugar.
2. Gum.
3. Jelly.
4. Sarcocoll.
5. Tan.
6. Bitter principle.
7. Narcotic principle.
8. Acids.
9. Starch.
10. Indigo.
11. Extractive principle.
12. Albumen.
13. Gluten.
14. Fibrina.
15. Oils.
16. Wax.
17. Resins.
18. Camphor.
19. Caoutchouc.
20. Sandarach.
21. Gum resins.
22. Wood.
23. Suber, or Cork.
24. Alkalies.
25. Earths.
26. Metals.

"The three last," Dr. Thomson judiciously remarks, "are scarcely entitled to the name of vegetable principles. It is highly probable," he adds, "that they are taken up ready formed, and deposited without alteration in the vegetables which contain them, whereas the other twenty-three genera consist of substances which owe their formation to the processes of vegetation." Of some of these, however, as the acids, oils, and resins, we have been under a necessity of treating in the preceding Lectures. I shall, therefore, not enlarge on them in this, but content myself with a reference to the lectures where they are to be found.

1. *Sugar* is a substance which is contained more or less in most vegetables. Some, how-

ever, as the sugar-cane and the sugar-maple of America, contain it in much larger quantities than others, so as to render the culture of these plants, and the preparation of the article from them, a matter of great commercial importance. Sugar is decomposed both by heat and mixture; and by the most accurate experiments it is found to be composed entirely of oxygen, carbon, and hydrogen. It is therefore a vegetable oxide. The proportions of these matters were found by Lavoisier to be

64	parts oxygen.
28	carbon.
8	hydrogen.
100	

These proportions must, however, vary considerably in the sugars produced from different plants, and they must frequently have united with them some heterogeneous matters. The beet, the carrot, the parsnip, the sap of many trees, and all the different kinds of grain, contain sugar in considerable abundance. According to the calculations of M. Achard of Berlin, twenty pounds of beet root will yield one of sugar, and a German square mile of land (sixteen square miles English) would produce white beet enough to furnish the Prussian dominions with sugar.

The saccharine matter is so profusely diffused in the vegetable kingdom, that we see the bees collect it in large quantities from the flowers of plants. Honey, however, differs in some respects from pure sugar; for besides sugar it contains mucilage and an acid. The sugar obtained in the usual way, and from honey, produces, when treated with the nitric acid, the oxalic acid, or acid of sorrel, which is composed of

77	parts oxygen.
13	carbon.
10	hydrogen.
100	

Thus we see that the same ingredients enter into the composition of this acid as into that of sugar itself, but in different proportions. In the oxalic acid it appears that the oxygen is in sufficient abundance to give it the acid character. This it probably in part obtains from the nitric acid used in the process.

2. *Gum* is a substance too well known to require any description. It is produced by several fruit-trees, even in this country; but that which is most plentiful in commerce, under the name of *gum arabic,* is the product of a species of mimosa.

Gum is found to consist of five ingredients:—oxygen, hydrogen, carbon, nitrogen, and lime; but these may be supposed to vary in different kinds. The species of gum at present known are four:—gum-arabic, gum tragacanth, cherry-tree gum, and the mucilage contained in the roots and leaves of several plants.

Gum tragacanth is stronger than gum arabic. It contains more of nitrogen and lime, perhaps more oxygen and less carbon.

Cherry-tree gum, which exudes from most of our stone-fruit-trees, is very nearly of the same qualities as gum arabic. It is, however, somewhat softer, and more easily melted.

Mucilage is contained in great quantities in bulbous roots, and in the foliage of those plants which have fleshy leaves, such as the althea, malva, &c. The bulbs of the hyacinth contain so much mucilage that they may be used as a substitute for gum arabic.

3. *Jelly* is procured from many fruits, particularly from the juice of ripe blackberries and currants. It must be carefully distinguished from the colouring matter of the fruit, as well as the sugar; for in a state of purity it is nearly colourless, though it has some taste, which is rather pleasant. Dr. Thomson conjectures that jelly is merely gum combined with vegetable acid.

4. *Sarcocoll* is contained in many plants, but in greatest abundance in a plant which bears that name. Liquorice and manna are classed under this head, from resembling sarcocoll in taste, and being soluble in the same menstrua.

5. *Tan*, or tannin, has been already noticed, and is a very important part of vegetables, if we consider its uses in the arts. Besides the tan

contained in oak bark, there are at least six other species, contained in—1st, Nut-galls; 2d, Catechu, which is obtained from a species of mimosa; 3d, Dragon's blood; 4th, Sumach; 5th, Fustic; 6th, Kino, an exudation from the brown gum tree of Botany-Bay. They all unite in the principle of astringency, and in striking a black colour with salts of iron. Common writing ink is a composition of gallat of iron and tannat of iron.

Pure tan, from nut-galls, is a brittle substance of a brown colour, and breaks with a vitreous fracture. The most important property of tan is its forming an insoluble compound with glue, or gelatine as it is called by chemists. The skin of animals consists almost entirely of gelatine, more or less hard and compact, according to the age and nature of the animal. With this the tan unites in the process of making leather; so that the skin is entirely altered in its nature by the process, and is formed into a third substance by the combination of gelatine and tan. This is a tedious process, the stouter hides requiring from eleven to eighteen months, and sometimes two years, before they are completely tanned.

6. The *bitter principle* is common to many plants, such as the quassia, the hop, &c. It has not yet been chemically examined, but nitrat of silver and acetat of lead will precipitate it from the infusions in which it is contained.

7. The *narcotic principle* is also contained in many plants; as the white poppy, which furnishes that well-known narcotic drug, opium. It abounds also in the deadly nightshade, and the foxglove; and most of the plants which have a milky juice contain a portion of it, such as the garden lettuce, &c.

Opium, however, does not consist altogether of the narcotic principle. It contains also resin and extractive matter. By repeated solution in water, and afterwards in alcohol, to take up the resin, the narcotic principle may be obtained pure in the form of white crystals. It is rather more powerful than opium; but its bad effects, as well as those of opium, may be counteracted by swallowing vinegar.

8. The *acids* have been already treated of in the lecture on Salts.

9. *Starch* is a well known substance. It is usually obtained from wheat flour, which consists entirely of starch and gluten. It is, however, a principal constituent in all kinds of grain, and also in the farinaceous roots, as the potatoe, the orchis, the sago plant, &c. Barley consists almost entirely of starch. "In the process of malting, which is causing the barley to begin to vegetate, a great part of the starch is converted into sugar. During this proces oxygen is absorbed, and carbonic acid gas emitted; whence it is probable that starch is converted into sugar

by diminishing its proportion of carbon, and increasing that of its hydrogen and oxygen. Its distillation shows us that it contains no other ingredient than these three*."

10. *Indigo* is a matter obtained by fermentation from the plant which bears that name; it may also be obtained from a plant well known in this country by the name of *woad*. It has been ascertained by experiment that indigo owes its blue colour to oxygen; and its constituent parts are oxygen, carbon, hydrogen, and nitrogen; the two first are in a large proportion.

11. *Extractive principle* is found in many plants, but very different in kind. Saffron yields it in great abundance. It has a near affinity, and perhaps connection, with the colouring matter.

12. *Albumen*, by which term chemists denote the white of an egg, or something analogous to it, is found in several plants, particularly in the juice of the papaw-tree of Peru.

13. *Gluten* is an essential part of all farinaceous vegetables. It may be obtained from wheat flour in abundance, by kneading it under a small jet of water till the fluid carries off all the starch, and runs off colourless. It has some resemblance to animal glue. It contains oxygen, hydrogen, carbon, and nitrogen.

---

* Dr. Thomson.

14. *Fibrina* is, as well as albumen, an animal matter, constituting the fibrous part of the muscles of animals. A substance resembling it has been detected in the juice of the papaw.

15. Of the vegetable *oils* we have already treated in the lecture on Combustibles.

16. *Wax*, though that which is used in commerce is collected by the bees, is in reality a vegetable substance, and it appears not to undergo any change whatever in its nature or character from the industry of those extraordinary animals, who merely extract it from the leaves of trees and other parts of vegetables. Like the oils, to which it bears a near relation, wax consists entirely of hydrogen and carbon. One hundred parts of wax contain

82·28 of carbon.
17·72 hydrogen.

100·

The myrtle wax, which is contained in the berries of the myrica cerifera of America, in its nature and general properties seems perfectly to agree with bees-wax.

17. Of *resins* I have partly treated in the lecture on Combustibles. It is well known that they exude from trees, particularly the firs. It is probable that resin is volatile oil, deprived of a portion of its hydrogen, and combined with oxygen.

18. *Camphor* has been already noticed in the lecture on Combustibles.

19. *Caoutchouc*, or elastic gum, called also Indian rubber, is a curious but well known substance, extracted from two trees of South America, the hævea and jatropha, and probably from some others of the same country. It exudes in the form of a milky juice, which concretes by exposure to the air. Its concreting appears, from some experiments, to be the effect of its absorbing oxygen. Caoutchouc is composed of carbon, hydrogen, nitrogen, and oxygen; but the manner in which they are combined is not known.

20. *Sandarach*, a resinous substance obtained from the juniper, is not a pure resin; for, when dissolved in alcohol, an insoluble residuum remains, which Dr. Thomson calls sandaracha.

21. *Gum resins* differ in many respects from resins. They are not so combustible, nor do they melt so easily. Their specific gravity is greater. They are only partially soluble in alcohol. They are supposed to consist of gum, or an extractive substance, and a body intermediate between oil and resin.—Galbanum, scammony, gum ammoniac, asafœtida, belong to this class.

22. The *wood* of plants, it is well known, consists of longitudinal fibres, easily subdivided into still smaller fibres. It is composed of oxygen, carbon, hydrogen, nitrogen, and lime.

23. *Suber*, or cork, is the bark of a species of

the oak. Nitric acid corrodes, dissolves, and decomposes it, converting it partly into suberic (a peculiar) acid, and partly into a substance resembling wax.

24. The only *alkalies* found in plants are potass and soda.

25. The only *earths* are lime, silica, magnesia, and alumina. Silica exists in many of the grasses and equisetums or horse-tails. That excellent philosopher Mr. Davy has demonstrated that it forms a part of the epidermis, or outermost bark, of those plants; and that the Dutch rush owes its property of polishing wood entirely to this circumstance.

26. The most common *metal* in plants is iron, and sometimes manganese.

Before I conclude this part of my lecture, I must add a few words upon that spontaneous change which some vegetable matters undergo, and which is called *fermentation*. This change generally takes place in those vegetable substances which contain a quantity of sugar and of mucilage, with a proper quantity of water, and a heat of from 60° to 70°. It is called the *vinous* fermentation, because in this way vinous fluids, including beer and cider, are prepared.

The old chemists established three stages of fermentation, the vinous, the acetous, and the putrefactive, though in reality they are three different processes.

The phænomena attending the vinous fermentation are—1st, An intestine motion or agitation in the fluid; 2dly, The fluid becomes thick and muddy; 3dly, The temperature increases; 4thly, Carbonic acid gas is evolved, and hangs over the fermenting liquor; 5thly, The fermentation ceases, the thick part rises to the top, or sinks to the bottom, and the liquor is entirely changed. It has lost its saccharine taste, its specific gravity is diminished. It is found to contain a quantity of alcohol, which may be separated from it by distillation.

To explain these phænomena, it must be remembered that alcohol, which is the essential part of every vinous fluid, consists of the same ingredients as sugar, only combined in different proportions. Alcohol contains more hydrogen, and less carbon and oxygen. In the process of fermentation, therefore, a considerable part of the oxygen and carbon contained in the fermenting fluid combine, and go off in the form of carbonic acid gas; and the quantities of these being lessened, while the whole of the hydrogen is left behind, the nature of the fluid is necessarily changed.

In the *acetous* fermentation the process is still more simple than in the vinous. It is well known that when any vinous fluid is exposed to the atmosphere, especially when acted upon by the sun's rays so as to raise its temperature, it is converted into vinegar. This entirely results from the absorption of oxygen from the atmosphere, by receiving a proper dose of which the fluid becomes acetic acid.

Putrefaction is a process more common to animal than to vegetable substances; but it also frequently takes place in the latter. As, however, ammonia is the general product of the putrefactive process, it is evident that all vegetable matter which undergoes it must contain nitrogen. The process of putrefaction is not so well understood as the vinous and acetous fermentations. It is, in fact, the entire dissolution of the whole body, in which new products are formed; but the principal circumstance seems to be that of the hydrogen and nitrogen combining together to form ammonia, without which no putrefactive process ever seems to take place.

Animal Substances.

The elementary principles of animal bodies seem to be much the same as those of vegetables. The compounds are less numerous. The substances usually found in the animal kingdom are as follows:

1. Gelatine.
2. Albumen.
3. Fibrina.
4. Mucilage.
5. Urea.
6. Sugar.
7. Oils.
8. Resins.
9. Sulphur.
10. Phosphorus.
11. Acids.
12. Alkalies.
13. Earths.
14. Metals.

1. *Gelatine*, it has already been intimated,

constitutes the principal part of the cutis, or skin, of animals. It is, however, found in other parts. The well-known culinary process of making jelly from calves' feet, and from the skin of a kind of sturgeon, called isinglass, produces at once the substance called in chemistry gelatine. If the calves'-feet jelly were evaporated to dryness it would be glue, and indeed glue is produced by boiling down pieces of the skin of animals, generally those parts which are cut off by the tanners and skinners: gelatine and glue are, therefore, the same. It exists more or less not only in the solid but in the fluid parts of animals; blood and milk always yield it, and it exists even in the bones, horns, and hair. It is a nourishing article of food, and constitutes the basis of soups. Gelatine consists properly of carbon, hydrogen, nitrogen, and oxygen. Phosphat of lime and soda are found in it, but are probably only held in solution by it.

2. *Albumen* is the white of the egg, in which, however, it is combined with sulphur and soda. It is also the chief constituent of the serum of blood. When heated to the temperature of 165°, it coagulates into a white solid mass of precisely the same weight. It is also coagulated by acids and alcohol. When dried, it becomes a brittle, hard, yellow substance, semi-transparent like horn. It must have a near affinity to gelatine, for by the action of nitric acid it is converted into that substance; and it consists of

the same ingredients, though probably in somewhat different proportions.

3. *Fibrina* is the solid or fibrous part of the animal muscles. It is prepared in the blood, from which it may be procured by washing the red clot which forms in blood, when the serum separates from it, till it has entirely lost its red colour. It may also be obtained, by a similar process, from the muscles or flesh of animals. It is of a white colour, and has no taste or smell. When exposed to heat, it contracts and moves like a bit of horn, exhaling at the same time the smell of burning feathers. In a stronger heat it melts. It has a near relation to the two former bodies, for nitric acid converts it into gelatine. It appears also to be composed of the same ingredients, but it probably contains more carbon and nitrogen, and less of oxygen.

4. *Mucilage* seems to be only the weakest and most diluted form under which gelatine appears, and ought therefore to be referred to the same head.

5. *Urea* is the essential constituent of that secretion (urine) from which it derives its name. It differs from all other animal substances in containing a larger portion of nitrogen.

6. *Sugar* has been found in animals in every respect similar to the sugar of vegetables, and particularly in milk.

7. *Oils*, as to their general properties, have been treated of in the lecture on Combustibles.

The animal oils are spermaceti, fat or tallow; train or fish oil, and butter. The first of these, spermaceti, is distinguished from all other oily bodies by the crystalline appearance it assumes. It is found in the skull of the spermaceti whale, and forms also a copious sediment in the oil of that animal.

8. *Resins* have also been already noticed. A resin is found in the bile of animals. Ambergris too is considered as an animal resin, being formed, as is supposed, in the stomach of the spermaceti whale. Castor, civet, and musk are also referred to this class.

9 and 10. *Sulphur* and *phosphorus* are also found in animals.—The latter exhales copiously in putrefaction in the state of phosphuretted hydrogen gas, and often produces those luminous appearances in putrid fish, &c., so terrifying to old women and children.

11. The *acids* which have been detected in animal bodies are the phosphoric, sulphuric, muriatic, carbonic, benzoic, uric, rosacic, amniotic, oxalic, acetic, malic, and lactic.

12. All the *alkalies* have been found in the fluids of animals.

13. The only *earths* that exist in animal bodies are lime, magnesia, and silica.

14. Of the *metals*, only iron and manganese have been found in animal bodies.

The parts of animals consist principally of the following matters :—

1st. The bones are composed of phosphat of lime, carbonat of lime, and gelatine.

2d. Blood, when suffered to rest, separates into two parts:—(1st.) The clot or thick part, which is fibrina, mixed with albumen and colouring matter. The colouring matter is chiefly an oxide of iron. (2d.) The serum is albumen and gelatine, mixed with muriat and carbonat of soda, and phosphat of lime. It coagulates in the same way as albumen.

3d. The muscular parts consist almost entirely of fibrina with some gelatine.

4th. The whole cutis, or skin, consists almost exclusively of gelatine.

5th. Horns, nails, hair, hoofs, and quills, resemble coagulated albumen.

6th. Milk is rather to be regarded as an adventitious matter, than one common to all animals. It is separable into two parts; *curd*, which resembles albumen; and *whey*, which consists of serum, sugar, and a peculiar acid called the lactic. Milk also evidently contains an animal oil, which is separated from it by agitation, in the form of that well known and nutritious substance butter. This seems chiefly to be contained in the curd part, when milk is separated by an acid into curds and whey.

INDEX.

A

Acetic Acid, its nature and properties, ii. 155 to 157.

Acids, canon of chemistry concerning their constitution, ii. 40. Their natures, kinds, and properties, 139 to 161.

Affinity (chemical), or elective attraction, explained, ii. 92 to 94.

Air, means of ascertaining its density, i. 74 to 78, 80. Its degree of expansion by being heated, ii. 57. See also *Atmosphere*, and *Pneumatics*.

Air-gun, principle of this instrument, i. 72, 73.

Air-pump, invention and explanation of, i. 64.

Alcohol, or ardent spirit; chemical account of it, considered as a compound combustible substance, ii. 202. Curious phænomena produced by its mixture with different acids, 209, 210.

Alkalies, simple substances in chemistry, ii. 33. Chemical account of them, 51. Their natures, kinds, and properties, 133 to 139.

Alumina, or Alum; chemical account of it, considered as one of the kinds of earths, ii. 175 to 179.

Ammonia, its nature and qualities, ii. 137, 138.

Amplitude, explanation of this term, i. 258.

Analysis, great progress which has been made in this operation by modern chemists, ii. 97.

Animal acids considered, ii. 159, 160.

Animal substances, different classes of them, ii. 279 to 283.

Antipodes, explanation of this term, i. 257.

Apparatus, chemical; lecture on, ii. 99. Advantages and disadvantages of vessels made of different materials, 99. Forms of vessels for different purposes, 102. Means of producing heat, 106. Constructions and objects of furnaces, 111. Lutes, 118. A large apparatus seldom required, 119.

Assaying metals, process of, ii. 285.

Astronomy, lectures on; see *Eclipses*, *Seasons*, *Solar*, *System*, and *Time*. Origin and dignity of this science, i. 241. Its history, 242. Explanation of the principal words and phrases used in it, 254.

Atmosphere, lecture on the phænomena of, i. 74. Inquiry concerning its height, 74. Winds, 80. Clouds, rain, &c. 89. Thunder and lightning, 110. See also *Pneumatics*.

Attraction, lecture on, i. 10. See *Chemical, Cohesion, Elective, Electrical, Gravity*, and *Magnetic*.

Azimuth, explanation of this term, i. 258.

Azote. See *Nitrogen*.

B

Banks of rivers, &c. cause of their blowing up, i. 38.
Barometer, principle of this instrument, i. 63.
Barytes, account of this kind of earth, ii. 188, 189.
Battery, electric, i. 103. Galvanic, 121.
Bellows, hydrostatic; principle of, i. 37.
Bells, electrical; experiment of, i. 108.
Boiling-point differs widely in different bodies, and is remarkably influenced by mechanical pressure, ii. 72. Degree at which water boils *in vacuo*, 73. Cause why water does not become hotter by being boiled long, 74. Curious result of an experiment to boil ether *in vacuo*, 76.
Boracic acid, its nature and properties, ii. 151 to 153.
Breezes, land and sea, in the tropical climates, accounted for, i. 82.
Burning-glasses, experiments with, i. 131, ii. 61. Curious experiment with concave mirrors used as burning-glasses, i. 170.

C

Calcination of metals, ii. 219.
Calendar, its reformation under pope Gregory, ii. 15.
Caloric, or elementary fire, a simple substance in chemistry, ii. 32. Chemical account of it, 33 to 35. Lecture on its chemical effects, 53:—its power of expansion, 53:—its distribution, 58:—its operation in causing fluidity, 62; and in the formation of vapour, 70:—its power of combustion, 79.
Camera obscura, its principle explained, i. 152.
Capillary attraction, phænomenon of, i. 11, 14.
Cataract, this affection of the eye explained, i. 177. The operation of couching for it, 177.
Carbon, or diamond, a simple combustible substance in chemistry, ii. 33. Chemical account of it, 49, 200 to 202.
Carbonic acid, its nature and properties, ii. 154, 155.
Catoptrics. See *Reflection*.
Cementation, description of vessels used in this chemical process, ii. 105.
Centre of gravity, account of it, i. 219.
Ceres, some particulars concerning this newly discovered planet, i. 280, 281, 294, 295, 296.
Chemical attraction, phænomenon of, i. 12, 13. Further explained, ii. 30.
Chemistry, lecture on its general principles, ii. 29. General illustrations of the effects of heat and mixture, 29, 30. Plan of the lectures on chemistry, 31. List of simple substances, and remarks on each, 32. Canons of chemistry, 35, 39, 40. Distinction of the terminations *ous*, *ite*, *ic*, *at*, and *uret*, 40, 161, 225. See also *Animal substances*, *Apparatus*, *Caloric*, *Combustible substances*, *Earths*, *Metals*, *Mixture*, *Salts*, *Vegetable substances*, and *Water*.
Clays, account of, ii. 176.

Clouds, phænomena of, i. 4. Their formation explained, 89.

Cohesion, phænomena of the attraction of, i. 11. Curious experiments to display this attraction, 16 to 18.

Colours, lecture on, i. 193. They do not reside in the objects themselves, but in the light, 193:—illustration of this remark, 194. Light first analysed, and separated into the different colours, by Newton; his experiments with the prism, 194. The theory of colours thus completely unfolded, 199. Beauty of a single prismatic ray, 200. Explanation of the phænomenon of the rainbow, 201. Principle of semipellucid bodies, 204. The blue colour of the sky and the green colour of the sea accounted for, 204.

Colures, explanation of this term, i. 258.

Combustible substances, lecture on, ii. 191. Explanation of the phænomenon of combustion, 191. Combustibles divided into fixed and volatile, 192:—also into simple and compound; account of the different kinds of the simple, 193; of the compound, 202 to 216.

Combustion, canon of chemistry concerning, ii. 39. Is one of the more general effects of caloric, 79. Distinction between combustible and incombustible bodies, 79:—the latter class ready to receive caloric, and give it out again in equal quantity, 79, 80;—the cases of inflamed spirit of wine, and sulphur, no exception to this assertion, 81. Combustion consists of a decomposition and a combination, 82.

Comets, account of, i. 298.

Compass, mariner's; its great utility, i. 25. Variation of the compass explained, 26. Dip of the needle, 27.

Condensing syringe, principle of this instrument, i. 72.

Conductors, metallic, fixed to buildings as a security against lightning, i. 115. Conductors of caloric, ii. 58, 59.

Constellations, account of, i. 249.

Copernican system of the universe, i. 245, 246.

Copper, its chemical properties, ii. 241, 242.

Cranes, principle of these instruments, i. 230.

Crystallization of salts, process and theories of, ii. 127 to 130, 132.

D

Day, the astronomical and the civil, ii. 4, 13, 14. The artificial day, 8, 9, 11.

Dew explained, i. 91.

Diamond. See *Carbon*.

Diana's tree, method of performing this experiment, ii. 239.

Digits, explanation of this term as used in speaking of eclipses, ii. 27.

Dioptrics, definition of, i. 157.

Distillation, description of vessels used for this process in its varieties, ii. 103 to 105.

Distorted figures reduced to symmetry by a cylindrical or a conical mirror, i. 170.

Divining circles, explanation of the experiment of, i. 29.

Drawing water; principle on which this effect is produced by a ship, and the proportion, i. 39.

E

Earth, opinions of the ancient astronomers concerning it, i. 243. Some particulars respecting it, considered as a planet, 280, 281, 294. Lecture on this subject, 318:—its figure, and illustrations of this, 318:—inclination of its axis to the axis of its orbit, 320:—mensuration of the earth, and way in which this was accomplished, 320:—the earth found to be not a perfect sphere, 324:—methods of ascertaining the longitude at sea, 326. General view of the materials of which this globe is composed; and different hypotheses on the subject, ii. 163 to 167. See also *Tides*.

Earthquakes, phænomena of, i. 6.

Earths, simple substances in chemistry, ii. 33, 52. Lecture on, 163:—definition of earthy and stony substances, 163:—different classes of them; remarks on each, and on their distribution, 164 to 190.

Eclipses, lecture on, ii. 17. Of the moon, 17. Of the sun, 21. Returns of eclipses as influenced by the nodes, 23, 24. Principles of foretelling eclipses, 25. Particular points and phases to be noticed in eclipses, 26. Explanation of the term *digits*, 27. Eclipses of the satellites of Jupiter, 27.

Ecliptic, explanation of this term, i. 258.

Electrical attraction, phænomenon of, i. 11.

Electricity, lectures on, i. 92, 105. Nature of the electric fluid, 92. Principal phænomena of electricity, 93. First discoveries in electricity, 94. Electrical machines explained, 98:—experiments with them, 100. Invention of the Leyden phial, 102. Discovery and explanation of the difference between positive and negative electricity, 105. Experiment of the electrical bells, 108. Account of the electrometer, 109. Explanation of the phænomena of thunder and lightning, 110. Electricity and galvanism are essentially the same, 122. Electrical mineral and animals, 123. Electricity a method of producing heat for chemical purposes, ii. 107.

Electrometer, account of this instrument, i. 109.

Ether, curious result of an experiment to boil it *in vacuo*, ii. 76. Chemical account of it, considered as a compound combustible substance, 211.

Evaporation, description of vessels used for this process in its varieties, ii. 103 to 106.

Expansion, one of the effects of caloric; experiments and illustrations on this subject, ii. 53. Bodies expanded by caloric, never increase in weight from its presence, 57.

Experimental philosophy, its origin and importance, i. 7 to 9.

Eye, its curious structure; its method of action, and some of its affections, explained, i. 173 to 181.

F

Falling bodies, principle on which they acquire an accelerated force, i. 208, 209.

Fermentation, a method of producing heat for chemical purposes, ii. 107. Chemical remarks on the nature of this process, 277, 278.

Fire-damp in coal-mines, ii. 45.

Fire-engine, its principle, i. 54.

Fixed stars, their number and distance, i. 248, 249. Difference between the period of their diurnal revolution, and that of the sun, 265, 266.

Flame, account of, ii. 192, 193.

Flint. See *Silica.*

Fluidity, one of the most general effects of heat, ii. 62. Even earths and stones of all kinds might probably be rendered fluid by the same means, 63, 79. List of the melting-points of different substances, 63, 64. Fluidity does not depend on the sensible, but the latent, heat of bodies, 65 to 70.

Fluids, canon of chemistry concerning their constitution, ii. 35. See *Hydrostatics, Hydraulics,* and *Pneumatics.*

Fluoric acid, its nature and properties, ii. 153.

Focus (of burning-glasses, &c.) explained, i. 138, 148, 151, 156.

Fountains, phænomenon of boiling, i. 5. Beautiful experiment of an artificial fountain, 71.

Freezing, its powerful effect in causing water to swell, ii. 54. Reason why deep lakes do not freeze, 60. Explanation how the process of freezing is so slowly performed, 66, 67. Experiment in freezing water from which the air had been extracted, 68. Agitation greatly assists the operation of frost, 68.

Friction a method of producing heat, ii. 107.

Fuel considered in its different varieties as a means of producing heat for chemical purposes, ii. 109 to 111.

Furnaces, construction of them for different chemical purposes, ii. 111 to 118.

Fusion, form and composition of vessels used in this process, ii. 102.

G

Galvanism, account of this science, i. 115. Its discovery, 116. Method of making experiments in it, 117. Different experiments, 117, 118, 122. Description of galvanic batteries, 121. Galvanism and electricity are essentially the same, 122.

Georgium sidus, some particulars concerning this planet, i. 297. See also 280 to 285, 294, 295. Account of its satellites, 314 to 317.

Glass, its advantages and disadvantages as a material for the composition of chemical vessels, ii. 99. Different shapes of optical glasses, and application of the principle of refraction to the construction of them, i. 145 to 157. Lecture on optical glasses, 172;—account of several; spectacles, 181, 182; —telescopes, 182, 186;—microscopes, 183.

Glucina, account of this kind of earths, ii. 190.

Gold, its chemical properties, ii. 237.

Gravity, or *gravitation*; phænomena of, i. 2. Explanation of this principle, 10, 14. Its force varies at different distances from the earth's surface, 207. Principle on which falling bodies acquire an accelerated force, 208. Account of the centre of gravity, 219.

Gum, chemical remarks on it, ii. 270.

Gutta serena, an affection of the eye, i. 178.

Gypsums, account of, ii. 173 to 175.

H

Hail, phænomenon of, i. 4. Its formation explained, 91.

Harmattan, the wind so called, i. 85.

Harvest-moon, this phænomenon accounted for, i. 306 to 311.

Heat, different means of producing it as an agent in chemistry, ii. 106 to 118. See also *Caloric*.

Hoar-frost explained, i. 91.

Horizon, explanation of the sensible and the rational, i. 254.

Hurricanes, their ravages, and probable cause, i. 84.

Hydraulics, lecture on, i. 44. Explanation of this name, 44. Cause why fluids rise to the level of their source, 44. Principle of the syphon, and experiments with it, 45, 47. Principle of intermittent springs, 48:—of the common pump, 49:—of the forcing pump, the fire-engine, and steam-engine, 53 to 55.

Hydrogen, or inflammable air, a simple substance in chemistry, ii. 33. Chemical account of it, 45, 194.

Hydrometer, principle of this instrument, i. 42.

Hydrostatics, lecture on, i. 31. Explanation of this name, 31. Water proved to be not incompressible, 31. Principles concerning the pressure of fluids, 32, 33, 35, 38, 39. Method of operation of some water-works, 32. Supposed constitution of fluids, 33. Springs on the tops of mountains accounted for, 35. The hydrostatic paradox, 35. The hydrostatic bellows, 37. Cause why the banks of rivers, &c. blow up, 38. Principle and proportion of a ship's drawing water, 39.

Principle of the tables of specific gravities, and the hydrostatic balance, 39. Method of ascertaining the density of different fluids, 41. Explanation of the hydrometer, 42.

I

Ice, experiment of liquefying it by means of the nitric acid, ii. 49. Cause of the cavities found in it, 55.
Inclined plane, principle of this mechanic power, i. 232.
Inflammable air. See *Hydrogen*.
Iron, its chemical properties, ii. 242 to 244.

J

Juno, some particulars concerning this newly discovered planet, i. 294 to 296.
Jupiter, particulars of this planet, i. 296. See also 280 to 285, 294, 295. Account of its satellites, 314 to 317:—their eclipses, ii. 27.

L

Laws of nature, explanation of this phrase, i. 6.
Lead, its chemical properties, ii. 245.
Lens, definition of this term, i. 140. Different sorts of lenses, and their effects, 146 to 157.
Levers, three different sorts of, and their modes and powers of action, i. 223, 227, 228.
Leyden phial explained, i. 102.
Libration of the moon explained, i. 306.
Light, lecture on, i. 124. Different opinions concerning its nature, 124. Its most remarkable properties, 125. Its astonishing velocity, 125. Its inconceivable rarity, 128. Its force, or momentum; curious experiment proving this, 134. Its constant motion in straight lines, 136. General principles and definitions concerning light, 137. See also *Colours*, *Reflection*, and *Refraction*.
Lightning. See *Thunder*.
Lime; chemical account of it, considered as one of the kinds of earths, ii. 167 to 175.
Loadstone, account of, i. 20. See also *Magnetism*.
Longitude, methods of ascertaining it at sea, i. 326 to 330.
Looking-glasses. See *Mirrors*.
Lutes (chemical), different sorts of them, ii. 118.

M

Magic lantern, its principle explained, i. 152.
Magnesia; chemical account of it, considered as one of the earths, ii. 184 to 188.
Magnetism, phænomena of, i. 11. Account of the loadstone, 20. Degrees of a magnet's force at different distances, 21. Ge-

neral power of loadstones, 22. Method of making magnets; and different kinds of them, 22, 23. Poles of the magnet explained, 23. Its principle of repulsion, 24. The mariner's compass, and its great use, 25. Different means by which iron may acquire the magnetic virtues, 27. Entertaining experiments in magnetism, 27, 29. Explanation of the reported miracle of Mahomet's coffin, 28.

Magnifying and diminishing properties of glass, i. 3.

Mahomet's coffin, explanation of the reported miracle of, i. 28.

Marls, different kinds of them, ii. 169.

Mars, particulars concerning this planet, i. 296. See also 280 to 285, 294, 295.

Mechanic powers, lecture on, i. 223. The six different kinds of these; the lever, 223:—the wheel and axle, 229:—the pulley, 230:—the inclined plane, 232:—the wedge, 234:—the screw, 235. See also *Motion*.

Melting-points of different substances, list of, ii. 63, 64.

Mercury, particulars concerning this planet, i. 295. See also 280 to 285, 294.

Mercury, its chemical properties, ii. 240, 241.

Metal, its advantages and disadvantages as a material for the composition of chemical vessels, ii. 101, 102.

Metals, simple substances in chemistry, ii. 38, 52. Means of detecting their adulteration, i. 40, 41. Oxidizement of them, ii. 41. Lecture on them, 217. Division of them into classes, 236, 237.

Microscope, invention of this instrument, i. 183. Description of its different kinds; the single microscope, 183:—the double or compound microscope, 184:—the solar microscope, 186.

Milky-way, i. 253.

Mineral acids, the principal, considered, ii. 139 to 155.

Mineral waters; substances usually found in them on analysis, and method of analysing them, ii. 251 to 266.

Mirrors; different kinds of them, and the method of their action: plane mirrors, i. 159:—concave mirrors, and optical deceptions with them, 163, 166, 169:—convex mirrors, 164. Experiment with concave mirrors used as burning-glasses, 170. Distorted figures reduced to symmetry by a cylindrical or a conical mirror, 170.

Mixture, lecture on its chemical effects, ii. 84. General principles with respect to mixture, 84. Instances of the mixture of solids with fluids, 85. Process of separating by heat, bodies differing in volatility, 86. Some bodies are less in bulk, and others greater, when mixed, 88. Different theories and explications of the effects of mixture; lord Bacon's, 88:—popular opinions after him, 89:—sir Isaac Newton's theory, 91. Affinity explained, 92. Some of the principal laws of mixture and solution, 94. Mixture a method of producing heat for chemical purposes, 107.

Monsoons explained and accounted for, i. 82.

Month, its period, ii. 14. Difference between a periodical and a synodical month, i. 304.

Moon, method of ascertaining her horizontal parallax, i. 286 to 288. Her diameter and bulk, 301. Period of her revolution round the earth, 302. Explanation of her phases, quarters, &c. 302, 303. Difference between her periodical and her synodical revolution, 304. Her revolution on her own axis, 305. Her libration explained, 306. Her year, 306. The phænomenon of the harvest-moon accounted for, 306. Explanation of the moon's nodes, 311. Appearance of her surface when viewed through a telescope, 313. Her mean distance from the earth, 316. Her eclipses explained, ii. 17 to 21. Her influence on the tides, Lecture XXII. (i. 331.)

Motion, lecture on the laws of, i. 207. Principles of gravitation, and of the *vis inertiæ* of matter, explained and illustrated, 207, 208. Great specific laws of motion, and illustrations of them, 212, 213, 218. Account of the centre of gravity, 219.

Mountains, reason why the highest parts of them are the coldest, ii. 61.

Muriatic acid, its nature and properties, ii. 150, 151.

Muriatic radical, a simple substance in chemistry, ii. 33. Chemical account of it, 50.

N

Nitric acid, its nature and properties, ii. 140, 141, 147 to 150.

Nitrogen, or azote, a simple substance in chemistry, ii. 33. Chemical account of it, 41.

Nodes of the moon explained, i. 311, 312. Their influence on eclipses, ii. 18 to 25.

O

Objects and principles (general) of these lectures explained, i 1.

Oils; chemical account of them, considered as compound combustible substances, ii. 212 to 216.

Opakeness and transparency, the principles of, i. 136.

Ores of metals, ii. 231 to 235.

Oxidizement of metals, ii. 220 to 231.

Oxygen, a simple substance in chemistry, ii. 32. Chemical account of it, 35 to 41.

P

Pallas, some particulars concerning this newly discovered planet, i. 280, 281, 294 to 296.

Paradox, the hydrostatic, i. 35.

Parallax, explanation of the diurnal and the annual, i. 259. Illustrations of the horizontal parallax, 286 to 293.

Pendulum, principle of its construction, i. 210.

Percussion a method of producing heat, ii. 107.

Phænomenon, meaning and derivation of this word, i. 74.

Phases of the moon explained, i. 302, 303.

Philosophical fireworks, how to make them, ii. 194.

Phosphori, solar, account of, i. 132.

Phosphoric acid, its nature and properties, ii. 160.

Phosphorus, a simple combustible substance, ii. 33. Chemical account of it, 47, 194 to 197.

Planets, lecture on the primary ones, 276:—nature of these bodies, and laws of their motion, 276, 277, 216:—the superior and inferior planets, 278:—tables of the diameters, magnitude, density, and solidity, of the sun and the primary planets, 280 to 284:—table of the inclination of the orbits of the primary planets from the plane of the ecliptic, 285:—method of measuring the distance of the heavenly bodies from the earth; the horizontal parallax of the moon, and of the sun, ascertained, 286, 290:—tables of the mean distance of the primary planets from the sun, and of their revolutions, 294, 295:—planets which have been lately discovered, 295:—particulars concerning the different primary planets; Mercury, 295; Venus, Mars, Ceres, Pallas, Juno, Vesta, and Jupiter, 296; Saturn, and the Georgium Sidus, 297. Lecture on the secondary planets, 301:—of the moon, 301:—the satellites of Jupiter, Saturn, and the Georgium Sidus, 314.

Platinum, chemical properties of this metal, ii. 238.

Pneumatics, lecture on, i. 57. Composition of atmospheric air, 57. Different classes of elastic fluids, 58. Weight of air, proved by experiment, 58. Its gravity varies at different altitudes, 59. Experiments to prove the pressure of the atmosphere, 61, 62. Principle of the barometer, 63. The air proved to be elastic, 64. Invention and explanation of the air-pump, 64:—experiments with this instrument to show the mechanical properties of air; its weight and pressure, 68; its elasticity and compressibility, 69.

Potass, its nature and qualities, ii. 135 to 137.

Precession of the equinoxes explained, i. 264, 265.

Prince Rupert's drops, ii. 100.

Prism; Newton's experiments with this instrument, to analyse light, i. 194, 195.

Prussic acid, its nature and properties, ii. 159.

Ptolemean system of the universe, i. 244.

Pulley; principles of this instrument, and its mode of acting, i. 230.

Pump, principles of the common one, i. 49:—of the forcing pump, and examples of it, 53, 55:—of the air-pump, 64.

Pyrites, ii. 198.

R

Rain, phænomenon of it explained, i. 4, 90.
Rainbow, phænomenon of it explained, i. 5, 201.
Rays of light, and their different kinds, explained, i. 137 to 139.
Reflection (or Reflexibility) of light, phænomena of, i. 2. Lecture on, 158:—principle of reflection, 158:—different kinds of mirrors, and their modes of action, 159 to 171.
Refraction (or Refrangibility) of the rays of light defined, i. 139. Lecture on, 142:—principle of refraction explained and illustrated, 142:—its application to the construction of optical glasses, 145.
Repulsion, some bodies possess a power of, i. 18. This principle exemplified by the magnet, 24.
Rust of metals explained, ii. 221.

S

Salts, lecture on, ii. 120. Definition of the term *salts*, 120. Phænomena in the mixture of salts with water, 122:—separation of the salts afterward by evaporation, 125. Process and theories of the crystallization of salts, 127, 129. Different methods of separating salts in solution, 131. Account of the alkaline salts, 133:—of the acids, 139:—the compound salts, 161; canon of chemistry concerning the constitution of these last, 40.
Samiel, the wind so called, i. 87.
Satellites; account of those of Jupiter, Saturn, and the Georgium Sidus, i. 314 to 317. Eclipses of those of Jupiter, ii. 27.
Saturation explained, ii. 85.
Saturn, particulars concerning this planet, i. 297. See also 280 to 285, 294, 295. Account of its satellites, 314 to 317.
Screw; principles of this mechanic power, and its mode of acting, i. 235.
Sea, its green colour accounted for, i. 205. Inquiries concerning its supposed gradual diminution, ii. 248, 249.
Seasons, lecture on their vicissitudes, ii. 1.
Semipellucid bodies, principle of, i. 204.
Shock (electric) explained, i. 98, 103.
Sidereal time, difference between that and solar, i. 266.
Signs of the zodiac, i. 250. Present difference between their nominal and real places, 264.
Silica, or flint; chemical account of it, considered as one of the kinds of earths, ii. 179 to 184.
Silver, its chemical properties, ii. 239.
Simple substances in chemistry, list of them, ii. 32.
Sirocco, the wind so called, i. 86.
Sky, its blue colour accounted for, i. 205.
Snow, phænomenon of, i. 4. Its formation explained, 91. Does

not contain a salt, ii. 55. Manner and degree in which it keeps the ground warm, 59.

Soap, its nature and composition, ii. 139.

Soda, its nature and properties, ii. 133 to 135.

Solar system, lectures on. See *Sun*, *Planets*, *Comets*, and *Earth*.

Solution, some of its principal laws, ii. 94. Description of vessels used in this chemical process, 106.

Specific gravity, explanation of this phrase, i. 15. Principle of the tables of specific gravities, 39, 40. The specific gravity of bodies differs with the degree of heat, ii. 57.

Spectacles, invention of, i. 182. Principle of those proper for short-sighted persons, 155, 181:—for the weak-sighted, 181.

Spirit of wine (highly rectified) affords more than its own weight of water by combustion, ii. 81.

Spots on the sun's disc, their number and magnitude, i. 270. Conjecture concerning them, 271. Discovery produced by means of them, 271.

Springs on the tops of mountains accounted for, i. 35. Principle of intermittent springs, 48.

Starch, chemical remarks on, ii. 273.

Stars, two sorts of, i. 247. Number and distance of the fixed stars, 248, 249. The constellations, 249. Unformed stars, 252.

Steam, its weight compared with that of water, ii. 72.

Steam-engines, their operation explained, i. 55, 56.

Steel, account of, ii. 243.

Steelyard, principle of this instrument, i. 226.

Stony substances. See *Earths*.

Strontian, account of this kind of earths, ii. 189.

Suction, the idea of this is a vulgar error, i. 69.

Sugar, chemical remarks on, ii. 268 to 270.

Sulphur, a simple combustible substance, ii. 33. Chemical account of it, 48, 197 to 200.

Sulphuric acid, its nature and properties, ii. 140 to 147.

Summer, our distance from the sun is greater in this season than in winter; this paradox explained, i. 262, 263.

Sun, its diurnal motion apparent and not real, i. 1. Experiment and calculation on the degree of its continual exhaustion, 134, 135. Lecture on the sun, and his real and apparent motions, 260:—constitution of the solar system, 260:—apparent diurnal and annual motions of the sun accounted for, 260:—his distance from us greater in summer than in winter; this paradox explained, 262, 263:—present difference between the nominal and real places of the signs of the zodiac, 264:—difference between solar and sidereal time, 265, 266:—form of the sun, 270:—spots on his disc, their number and magnitude, 270; conjecture concerning them, 271; they produce the discovery of his form, and revolution on his axis, 271:—phænomenon of the zodiacal light, 272. Tables of the diameters, magnitude, density, and solidity, of the sun and the primary planets, 280 to 284. Method used for ascertaining the sun's horizontal parallax, 289 to 293. Tables of the mean distances of the primary planets from the sun, and of their revolutions, 294, 295. The sun's influence on the tides (Lecture XXII.), 331, &c. His eclipses explained, ii. 21 to 27. His rays used as a method of producing heat for chemical purposes, 108.

Syphon, principle of this instrument, i. 45, 46. Experiments with it, 46, 47. Natural syphons, 48.

System of the universe, lecture on, i. 241. Opinions of the ancient philosophers on this subject, 243:—the Ptolemean system, 244:—the Copernican, 245:—the Tychonic, 246. The stars, planetary and fixed, 247:—constellations, 249:—unformed stars, 252. The milky-way, 253.

T

Talcs, account of, ii. 186.

Tan, chemical remarks on it, ii. 216, 271, 272.

Tantalus's cup, experiment of, i. 47.

Tartaric acid, its nature and properties, ii. 157, 158.

Telescope, invention of this instrument, i. 182. Description of its different kinds; the dioptric or refracting telescope, 186:—the achromatic, 189:—the reflecting, 190:—the Gregorian, 191:—the Newtonian, 191:—Dr. Herschel's great telescope, 192.

Terminations (chemical), OUS, ITE, IC, and AT; distinction of, ii. 40, 161:—URET, 225.

Thaw, explanation how it is so slow in its operation, ii. 66.

Thunder and lightning, explanation of the phænomena of, i. 3, 110. Dr. Franklin's experiment by which he brought down lightning from the heavens, 110. Signs of thunder-storms, 112:—safest situations during them, and method of calculating the distance of the cloud, 114. Description and explanation of the conductors fixed to buildings, 115.

Tides, phænomena of, i. 5. Lecture on, 331:—their daily, monthly, and annual periods, 332:—Newton's theory of the tides, 334:—explanation of their principal phænomena, 337.

Time, lecture on the divisions of, ii. 1:—different measures of it which have been adopted; the day, 4 to 14; the month and the year, 14, 15:—cause of the difference between mean and solar time, 5.

Tin, its chemical properties, ii. 244.

Torricellian experiment, i. 62.

Trade winds explained, i. 81, 340.

Transits of Venus in the years 1761 and 1769, important points ascertained by means of them, i. 289 to 293.

Transparency and opakeness, the principles of, i. 136.